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LIGHT AND VISION

Man's basic anatomical and physiological equipment for visual reception has remained unmodified over many centuries. His understanding of how best to serve visual requirements through external facilities has been amplified during some of those centuries, but the real gains belong to the present. During the past decade the tempo has so accelerated that in a just sense it may be urged that a revolution marks man's immediate grasp of the environment as best it may be made to serve in the usage of his visual equipment.

This revolution culminated in a three-day conference at the University of Michigan, Ann Arbor, in March, 1958. This conference was developed and conducted by the University of Michigan's Institute of Industrial Health, School of Public Health, Vision Research Laboratories, Bureau of School Services, College of Architecture and Design, Department of Physics, School of Education, and by the Michigan Department of Health, the Michigan Department of Public Instruction and the Illuminating Engineering Society.

The scientific presentations of this conference almost equally were divided between the medical, the physiologic and the hygienic on the one hand and the architectural and engineering on the other. By no means was the focus on industrial lighting requirements. The manuscripts of the first group have been allotted to this special issue of this Journal. The remainder are in process of publication in the same format. In short course the two lots will be assembled into the proceedings of this conference on Light and Vision. The achievement of these proceedings is the enterprise of the School of Public Health of the University of Michigan. This complete publication will become available at cost in the winter of 1958 through H. E. Miller, Director, Continued Education Service, School of Public Health, 109 South Observatory, Ann Arbor, Michigan.

One of the virtues of science is the willingness to relegate to history and museums that which no longer is serviceable, or at least to mark all such as no longer the best. Prior to the Ann Arbor Conference too many sacred cows were being nurtured in the fields of vision and lighting. Recognizing the prior achievement of no ultimates, the Ann Arbor Conference was a mission of slaughter of vision and lighting fallacies.

In this featured issue *Industrial Medicine and Surgery* presents the industrial medical, the medical and the physiological portions of the records of that conference.

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Ophthalmic Aspects of Light and Vision

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The causes of poor vision from the ocular point of view can be grouped under two major headings — those conditions produced by normal biological variations in the size or shape of the eyeball with particular reference to its optical properties, and those conditions in the eye, the optic nerve or the visual pathway which have been produced by injury or by specific disease conditions.

By far the most common conditions affecting sight are those which many scientists believe to be the result of biological variations in the size, shape and optical properties of the structures of the eye, or in the binocular use of the two eyes. It is variously estimated that somewhere between 4% and 10% of those persons with ocular symptoms who consult an ophthalmologist, optometrist or eye clinic have an eye disease or injury, whereas the remaining 90% to 96% have a refractive condition or difficulty in using the two eyes as a team. This can be helped with glasses or with training in the binocular use of the eyes.

Lenses as aids to vision were known by the ancients and mention of them was made by Roger Bacon in 1268. It is a coincidence that convex lenses became available for persons of middle age and beyond approximately 100 years before the printing press was invented.

When a baby is born, the eyeball is on the average only two-thirds of the length that it will be in the adult. In relation to the focusing powers of the eye, the eyeball is short and the average young child is said to be hyperopic, parallel rays of light from a distance of greater than 20 feet not being brought to a clear focus on the retina except by increasing the curvature of the lens over that in a state of rest. As we grow, new cells are added to the cornea and to the lens in the eye and these changes and additions continue to take place throughout life. The development of the cornea and the lens may change the radius of curvature of these structures over a period of time and also therefore change their optical properties. The greatest growth in axial length of the eyeball occurs before the age of eight or 10 years. However, even when children are ready to go to school, a fairly large proportion still have a short eyeball in relation to its focusing power. Therefore it is necessary for these children to contract the ciliary or focusing muscle inside the eye, which permits increasing the magnifying power of the lens, in order to get a clear image on the retina even for objects at a distance. It follows that the focusing required for near objects, as in reading, is greater than in the optically perfect eyeball where for distant vision the image would fall on the retina without using the ciliary muscle. Some children, possibly 10% to 15%, have so much hyperopia in first grade that they cannot use their eyes for close work for very long without developing such symptoms of discomfort as headaches, eye fatigue and nervousness. Many such children, if not provided with compensating glasses, will simply stop trying to read and will look around the classroom or out the window. They can easily be helped with convex lenses, just as middle-aged persons with presbyopia are helped by this kind of lens.

Nearsightedness or myopia is just the reverse of hyperopia. In nearsightedness, the focusing power of the eye and the length of the eye are such that when one is looking at distant objects and the lens is in a state of rest, the focal point of the image falls in front of the retina, rather than on it; thus the image that falls on the retina is indistinct. Tensing the ciliary muscle in order to produce a more clear image on the retina is of no help in myopia since this makes the effect of the lens stronger and therefore makes more of a blur on the retina. However, a myopic person does get a clear image for his nearpoint work without glasses. The focal distance for keenness of the image depends upon the degree of nearsightedness. Myopic persons are most happy working in that area which is nearest to them. They usually enjoy reading

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books; many of them go into the garment and needle trades or do other kinds of near work. They can perform these near tasks without visual fatigue over a period of many hours because their focusing muscles are in a state of rest. However, the only way in which they can see things clearly at a distance is to wear compensating concave lenses.

As children grow, those who are hyperopic tend to become less so and those who are nearsighted tend to become more, these conditions being produced by the length of the eyeball in relation to its focusing properties.

Astigmatism is a more complicated condition, arising because the radius of curvature of one meridian of the cornea or lens is not the same as that for another. If this irregularity in curvature is very small, it can be ignored and may not cause a person any trouble. If it is more than minimal, it may produce headaches and one may never have a clear image on the retina unless he wears compensating cylindrical lenses. As in hyperopia and myopia, changes of growth and development, particularly during childhood and adolescence, may bring about changes in the kind and degree of astigmatism. It is most important that children with any of these conditions have thorough professional eye examinations periodically because even within a period of six months to a year it may be necessary to change their glasses to give them clear comfortable vision.

Myths About Optical Defects

There has been a great deal of misunderstanding about these refractive conditions. All of us interested in light and vision should help to correct the misconceptions which are so common concerning these eye problems. These conditions actually are variations that one should expect from the biological norm, just as there are physiological variations in height, weight, hand size and foot size. Parents take it as a matter of course that the young child for a period of several years has his feet grow so fast that he often outgrows his shoes while they still are in good condition despite the rough wear they get. Yet these parents, and sometimes unfortunately their well-meaning friends, get very much upset if their child develops myopia during this time, or if his glasses need to be changed for a higher lens power. As a matter of fact, if the optical properties of the cornea, the lens and the rest of the eye remain constant, the eyeball itself might need to grow in length less than 1/100th of an inch for a child with myopia to need to have his glasses changed or, if he does not have myopia already, to need glasses for myopia. If a child varies only 1% in his total body height from the average for his age, this would not be considered anything of moment. It is considered important with regard to his eyes because in order to get ahead in school he needs to see the blackboard clearly, he wants to see clearly the picture on the television set at home and he wants to be able to read the street signs as he goes about the town. Were a nuclear war to throw us back into the days of the cave man, so that we wouldn't be traveling the highways in 300 horsepower automobiles and trying to find our way around modern cities, a myopic person would not be too badly off. He probably would be considered one of the important people in the tribe, since he would enjoy working at making arrowheads or pottery, where his near vision would aid his work. Those fortunate persons in the tribe whose eyes happened to have just the perfect optical qualities for distant vision would be the ones who would be assigned as look-outs for the enemy tribe and for predatory animals. Since all the printing presses would probably be destroyed in such a catastrophe, presbyopes would have nothing to read and could get along fairly well without glasses.

A great deal has been written about the causes of these refractive conditions, the dietary, hereditary and other factors that may influence them. So far as we know, however, there is no acceptable scientific evidence that use of the eyes produces any of these conditions. Nor is there evidence that using one's eyes will make any of these conditions worse. There is no evidence that wearing glasses will weaken the eyes, nor that they will strengthen the eyes. These superstitions come about because hyperopia in the average person tends to decrease as he grows up; therefore he can wear weaker lenses. Such a person may jump to the conclusion that wearing glasses has strengthened his eyes. In general myopia tends to get worse as one grows older. In such an instance it is easy to jump to the conclusion that wearing glasses has weakened the eyes. The truth is that in neither condition has wearing the lenses, and I am convinced that this is also true of contact lenses, had any effect on the refractive condition. All that the proper glasses will do is to provide clear and comfortable vision, in the same way that good lighting helps provide these benefits.

Sometimes persons interested in illumination have made use of statistics showing the increase in myopia among school children, this being the condition that is found most often by the simplest vision screening test given. Such tests show a higher proportion of children with visual problems in the various grades as they get older, inasmuch as myopia increases with age not only among school children in the more highly civilized nations but in areas where children never learn to read and write. Many have been misled by

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Dr. Herman Cohn of Germany who, about 80 years ago, attributed myopia among school children to using the eyes under conditions of very poor illumination, which at that time I understand was as low as one foot-candle in some schoolrooms. There is no question that Dr. Cohn made a significant contribution in calling attention to the need for better seeing conditions in our schools. However, while the illumination of classrooms in all of the civilized countries has improved possibly 30-fold since Dr. Cohn's day, there has been no decrease in the extent or incidence of myopia.

In the St. Louis Study of school vision screening procedures which was sponsored by the United States Children's Bureau, the National Society for the Prevention of Blindness and the Washington University College of Medicine, among 1,078 eyes of first grade children examined by the ophthalmologists, we found 3% with some degree of myopia or myopic astigmatism and among 1,218 eyes of children in sixth grade, we found 9%, or more than three times as much myopia and myopic astigmatism. However, when we look at the data on hyperopia and hyperopic astigmatism, we find a decrease with age. Among the 1,078 eyes of first-grade children we found about 19% with hyperopia or hyperopic astigmatism of two diopters or more, while among 1,218 eyes of children in sixth grade, we found only 9% or less than half the proportion.

Myopia, astigmatism and hyperopia do not always change at a regular rate. In some children the condition seems to remain stationary for two years or longer. Some people have given eye exercises to children with these conditions and if the condition did not then progress have leaped to the conclusion that the eye exercises have "arrested" the condition. Although I am familiar with many such claims, I have not seen any research studies which confirm these conclusions. On the contrary, some studies have been made which indicate that visual training is without effect in these conditions except as the visual training would help any person in the better perception or recognition of the test letters on a chart.

Causes of Blindness

Injuries and diseases producing loss of sight are far less common, fortunately, but far more serious when they do occur. Miss C. Edith Kerby, of the National Society's statistical division, estimates that in 1957 there were 339,000 blind men, women and children in the United States. If all these men, women and children were gathered together in one community we would have a city seven times the population of Ann Arbor — a veritable city of darkness. The greatest tragedy of blindness is that so much of it is preventable — about 50% if the proper thing had been done at the right time. Fortunately, a good deal of progress has been made. Only 20 years ago it was estimated that about 10% of all blindness was due to injury; at the present time our estimates are that only 5% of blindness is due to this cause. Much has been accomplished in the larger industries in providing proper eye protection to all workers employed in shops where operations are being carried on that might be hazardous to the eyes. A good deal remains to be done about promoting eye safety in smaller plants, on the farm, in home workshops and in college and vocational school shops which are lagging behind our better industries. The National Society is promoting eye safety in schools, colleges and industry through the Wise Owl Club. This incentive program for eye safety gives recognition to the workman who had an industrial accident but whose eyesight was saved because he was wearing safety glasses which management provides. Although this program has been going on for only 10 years, we now have records of more than 14,000 men and women who have had the sight of at least one eye saved because of wearing safety glasses, and about one-fourth of this number had the sight of both eyes saved. This is one instance where we can actually point to how prevention has paid off.

Eye infections formerly were a leading cause of blindness. In 1908 when the National Society was established, a single eye infection, babies' sore eyes, was the cause of 28% of blindness among children in a state school for the blind. Today, this cause of blindness has virtually disappeared because of the use of prophylactic drops in the eyes of all newborn babies. Other diseases such as syphilis have been brought under better control. As a result, at the present time only 10% of blindness is estimated as caused from infection, and the use of the newer antibiotic drugs is cutting down on the incidence of these conditions.

Certain chemical substances such as wood alcohol and lead taken into the body may produce blindness because of their effect upon the optic nerve and the visual pathway. These poisonings, together with the oxygen which formerly was given uncontrolled to many premature babies, account for about 3% of all blindness. However, that produced from oxygen has virtually disappeared as we have learned how to use it to save babies' lives without blinding them by keeping the concentration low and giving it for minimal periods of time.

About 16% of blindness is produced by the effects of general diseases such as diabetes, hardening of the arteries and high blood pressure, which may affect the small blood vessels

of the eyes. The only known way to avoid loss of sight from these conditions is to have the earliest possible diagnosis and to keep the patient under optimum treatment.

Heredity and other prenatal factors that are not well understood are responsible for 13% of blindness. A number of eye conditions are inherited, some as a dominant characteristic, some as a recessive, and some as sex-linked characteristics. Because some eye diseases can be inherited in any one of these three ways, it is not possible to give advice concerning heredity to a person with these conditions unless one knows the family history of the condition, and this may mean going back for three generations. The possibilities for prevention are not entirely clear but I feel that if a child has a hereditary eye condition, at least an investigation should be made as to the mode of inheritance and the boy or girl advised about this before they are old enough to think about falling in love, getting married and having children. Although this information formerly was not provided, more schools today are providing it to children at the high school level.

There remains about 50% of blindness, the underlying causes of which are not thoroughly understood. Prominent in these groups is cataract, a cloudiness of the lens, which occurs most commonly among people in their 60's and 70's and accounts for 18% of blindness. There are still many persons with cataracts who could have had their sight restored through surgery, which is successful in 95% of the cases if it is done at the right time. Surgery is too often postponed because of fear or ignorance. Another far too common cause of blindness is glaucoma, increased pressure inside the eyeball which arises because of something interfering with drainage of the aqueous fluid from the eye.

Glaucoma is a most insidious condition because it can exist for many months or years, gradually stealing sight without pain or obvious symptoms, and may not be discovered unless a fairly thorough eye examination is done. If glaucoma is discovered early, in most cases it it possible to arrest the condition and prevent blindness through medical or surgical treatment. If it is not discovered until it is well advanced, the chances of arresting further progress of the condition are slim. Glaucoma is far more common among persons over 40 years of age, occurring, according to surveys sponsored by the National Society, in 2% of such persons. Glaucoma is one of the reasons why persons in their 40's, who find that their eyes do not focus clearly when reading the newspaper because of the gradual loss of elasticity of the lens and of muscle tone, should have a thorough professional eye examination, rather than drifting down to the nearest five and dime store "to fit themselves" with a pair of reading glasses from the ocular bargain counter.

Need For Proper Light For Visually Handicapped

Concerning the possible relationship of illumination to these various sight stealing diseases, there is no causative relationship. There is no evidence that the type of illumination, its quality or quantity has anything to do with the production of any of these diseases of the eye and there is no evidence that use of the eyes has any relationship to these diseases. If one has cataracts, glaucoma, diabetes or a hereditary eye condition, there is no evidence that using the eyes will make the condition worse. The only possible causative connection with illumination is with eye injuries, where I believe that inadequate illumination affords a setting where it is more likely that work accidents may occur. There is no evidence that television, movies or homework damages the eyes. I am convinced that good illumination is most important in our schools and in our offices. But the job of selling it to our children and to our associates should be done because it enables them to see more comfortably and easily and increases visual efficiency — not by making use of pseudoscientific reports implying that good illumination is a means of "protecting the eyes."

There is considerable clinical evidence that persons with astigmatism, hyperopia or eye disease can use their eyes much more efficiently and comfortably if they have better than average illumination. It is well recognized that as a person gets older he needs more light. It is well known that if a person has certain kinds of eye disease, such as macular degeneration or other conditions involving the retina, more light enables him to read better. There are certain exceptions to this — some albinos, persons with inflammation of the iris or lack of a portion of the iris who suffer from photophobia, and persons with a cataract limited to the central portion of the lens, who can see better under conditions of poor illumination because then the pupil is more widely dilated and the rays of light from an image can pass through those parts of the lens which are clear, rather than the central part which is opaque. Recent studies have shown the effects of glare discomfort in persons with relatively normal vision. But those who wear glasses that are scratched or blurred with fingerprints, and those with corneal, lens or other changes in the ocular media through which the light rays pass, will experience greater effects from the scatter of these rays. The scatter effect produces veiling haze unless glare is carefully controlled when using daylight or higher levels of electric illumination.

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Prevention of Sight Loss

Although we do not know how to prevent such conditions as hyperopia, astigmatism and myopia, which are normal biological variations in the focusing ability of the eye in relation to its shape and length, we do know a great deal about how to prevent the various eye diseases that have been discussed. Some of these such as infections and injuries can be prevented even before they happen. Retrolental fibroplasia, the disease which has blinded 8,000 small premature babies, is now being prevented by proper use of oxygen which is necessary to save life. For other eye diseases, prevention of loss of sight is based on early detection of the condition through periodic eye examinations, mass eye screening and provision of proper treatment. Support of fundamental and clinical research in the diagnosis, treatment and prevention of these conditions also will help to cut down on the extent of unnecessary blindness in future years. Adequate illumination, though it has no effect in the causation of these conditions, is important not only for persons with good vision but even more for those with deficient sight in order to provide eye comfort and ease of seeing, and to avoid headaches, nausea and the unnecessary expenditure of nervous energy in seeing.

Design for Trauma

Professional boxing is a foolhardy and hazardous enterprise and many of those engaged in it eventually suffer a variety of serious injuries that may impair their subsequent well being. Boxing is a brutal business, a holdover from a less enlightened era and not too far removed from the gladiatorial contests of ancient Rome. Medical evidence supporting the thesis that unavoidable and irreversible injuries are sustained in boxing has been presented. Boxing is the only major sport in which traumatization is the prime objective and not an accidental accompaniment. The impacts are meant to impair the physical and neurological reactions of the opponent for the count of ten at least and some of them have been more permanent. It is a design for trauma. Sometimes death! There should be a physician in every boxer's corner to attend to his medical needs between rounds. A medical man of competence and judgment who would recognize injuries and could stop the proceedings at any time, would replace one of the so-called seconds. The contestants aim at a knockout. Achieving such a result requires a certain amount of concussion of the brain. This is bound to be dangerous, may be injurious and can be lethal. There are also many less devastating injuries to the head that make boxing a specially imprudent and perilous venture. Blows to the solar plexus, carotid sinus, chest, heart, face and kidney can result in serious injuries and have been known to cause death. The carotid sinus is vulnerable to what may appear to be slight trauma and may be followed by loss of coordination, consciousness and proper respiration. Blows to the chest can result in lung damage. Sudden compression may cause a reflex closure of the glottis and sufficient internal pressure to rupture some alveoli of the lung. Men in the water have experienced similar results when subjected to the pressure of underwater explosions. Trauma over the heart can produce a state of collapse due to circulatory deficiency, shock or emotional imbalance. Serious ventricular fibrillation has been recorded. Damage to the eyes is of frequent occurrence and serious consequence. Some boxers have suffered lacerations of the cornea, tears of the iris, detachment of the retina, hemorrhage of the posterior chamber and changes in the macula. Cerebral trauma is almost inescapable and may result in concussion, aphasia, double vision, recurrent headaches, difficulty in walking, tearing of the meninges, subarachnoid hemorrhage, rigor vitae and rigor mortis. In view of the inherent possibilities of serious injuries associated with boxing, rigid rules should be established by law to protect the physical well being of the contenders. The boxing commission should establish a legal code whereby each boxer is assigned a well-trained physician armed with authority to stop the contest at any time if in his sole opinion his boxer is injured, outclassed or his ability to defend himself is impaired. Thus there would be three disinterested persons who could stop a fight at any time, the referee and the two physicians assigned to the fighters. Stopping the fight after the first injury is not preventive medicine but sometimes it is the several punches received after a heavy initial blow that can do the most damage and if this rational code were established these injurious blows might be prevented.

— Charles Sellers, M.D., in *Detroit Medical News*, October 6, 1958.

Effects of Illuminance Quantity on Accommodation of the Eyes

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Seeing a near object singly and sharply occurs only with great difficulty if the object is viewed with poor contrast against a dim background. The problem, of course, has many facets some of which are covered elsewhere in this symposium. The present report directs attention to one aspect which has received comparatively little attention, i.e., the effects of poor illuminance on the oculomotor system. It will be shown that several different (but perhaps closely related) oculomotor effects are associated with reduction in the quantity of illuminance. Some oculomotor effects, for example the variation in pupil size with illuminance, are reasonably well understood[1] and will not be alluded to again. On the other hand, while some of the effects of illuminance on the accommodation and vergence functions of the eyes have been known for some time[2,3] we still know precious little about optical and physiological changes which may be related to them. What follows is a description of experiments (some of them still under way) designed in the attempt to elucidate these phenomena.

Method

Essentially the subject was required to focus his eye (the other one was occluded) throughout the range of all possible stimuli to a change in focus. To achieve this he fixated a test chart at the other end of the room and tried as best he could to read the letters on the chart as different strengths of plus and minus lenses were placed before his eye. The apparatus is illustrated in Figure 1. For each stimulus to a focus change (that is, for each power of lens before his eye) three measurements were made of the actual amount of accommodation the eyes exerted. This was achieved by setting the point source of light (which was seen by reflection in the half silvered mirror mounted on the arms of a Badal optometer) until it was seen in sharpest focus. The position of this point source of light was then read from a scale and if one knows the optical characteristics of the optometer lens, as well as the lenses before the subject's eyes, one can compute from these data the position of the retinal conjugate focus (and hence the accommodation state) of the eye. The details of this method have been outlined in previous publications.[4,5]

The reflected image of the point source of light was seen superimposed on the test chart and its intensity could be reduced until it was seen barely above threshold against the background. The subject had to be careful to concentrate on reading the letters and to observe the small point of light (the stigma) in a completely passive way. The intensity of the illuminance on the test chart was varied by placing neutral filters before the projector which illuminated the chart. In some of the experiments, the sizes of the letters on the chart were varied so that they were always vis-

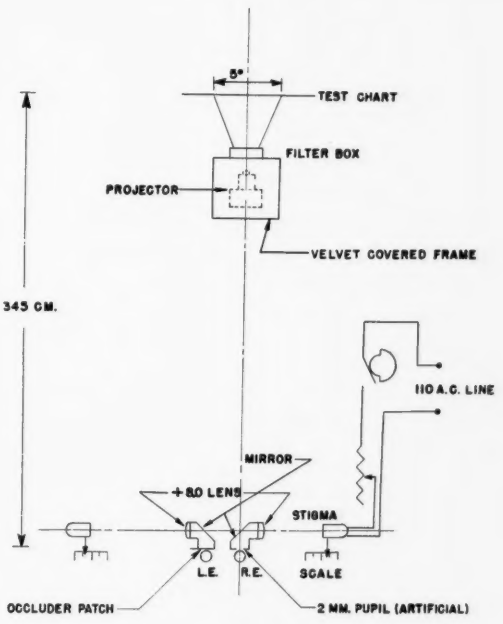

Figure 1.
Diagram of the apparatus used in some of these studies.

ible; in others, the test letters maintained a constant size as the background illuminance was varied. The major findings were essentially the same with the two methods and have been averaged together in the results which are described below. The stray light in the room was carefully screened from the observer's eye and the observer was adequately adapted to the level of the background illuminance before any measurements were made.

Results

The essential feature of this method as distinguished from much of the earlier work is that facilities were provided to measure how much the eye actually accommodated as well as the changes in the stimulus to accommodation. The result of a typical experiment at a high level of background illuminance is given in Figure 2 which shows the measured accommodation response (ordinate) as the accommodation stimulus (abscissa) was changed. Such a method for studying accommodation function was developed by Fry about 20 years ago.[6] If the accommodation response followed the change in accommodation stimulus exactly, the data would all fall on the sloping straight line. Over a wide range the observer did in fact accommodate more or less precisely as the accommodation stimulus was changed. As is the case with most physiological variables, however, there were limits to the region over which the accommodative response could keep pace with the stimulus. There were of course two of these, the upper limit and a lower limit and these limits are respectively referred to as the near and far points of accommodation. The difference between these two values is called the amplitude (or range, or breadth) of accommodation. One other bit of information supplied by such data is derived from the middle

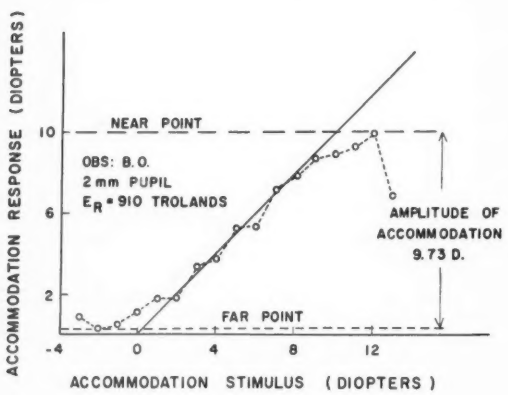

Figure 2.
Accommodation response for various values of the accommodation stimulus at the highest level for one young observer.

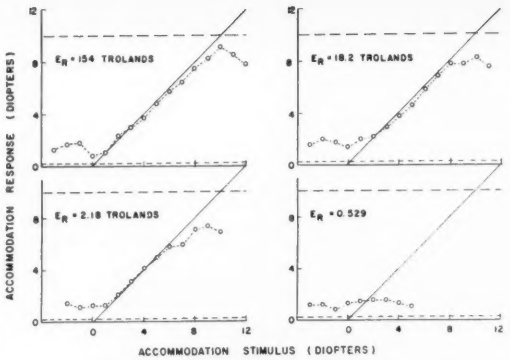

Figure 3.
Four experiments similar to those illustrated in Figure 2 carried on at different levels of retinal illuminance. The dotted lines represent the far and near points obtained at the highest level of illuminance (i.e., that illustrated in Figure 2).

range of the curve where it is more or less linear. The slope of this line represents the extent to which a one diopter change in accommodative stimulus (within the range where a positive accommodative stimulus evoked a positive response) could evoke an accommodation response. This might be termed the effectivity of the accommodation stimulus.

The effect of varying the level of background illuminance on the chart on these dependent variables is illustrated in Figure 3. This figure shows four curves similar to the curve in Figure 2 except that each was carried on at a different level of illuminance of the test chart. It is clear that even small reductions in the illuminance resulted in an approach of the far point (so called night myopia[7]) as well as a recession of the near point (so called night presbyopia[7,8]). While it is not so clear in the data of Figure 3, there was also a reduction in the effectivity of the accommodative stimulus to evoke an accommodative response. At the lower levels of illuminance — approximately 0.5 trolands* for the observer illustrated in this figure — there was virtually no accommodative response at all as the stimulus level was changed.

The quantification of all three of these effects as the illuminance of the chart was varied is illustrated in Figures 4, 5 and 6 which give the mean data obtained on four young adult observers.

Discussion

These experiments clearly demonstrate the deleterious effects of reduction of illuminance on

*A troland is the unit of retinal illuminance. It is the amount of illuminance falling on the retina of an observer who looks at an object of luminance 1 candle/meter^2 through a pupil 1 mm^2 in area. The retinal illuminance in trolands is computed by multiplying the area of the pupil by the luminance of the object viewed.

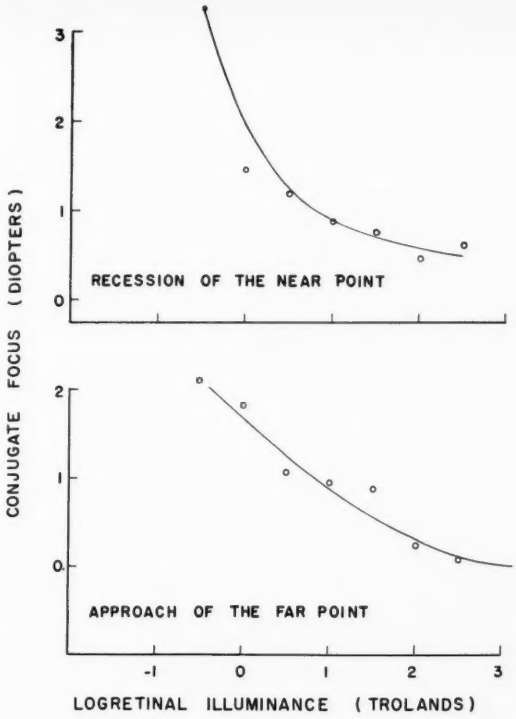

Figure 4.
Recession of the near point and approach of the far point as a function of retinal illuminance.

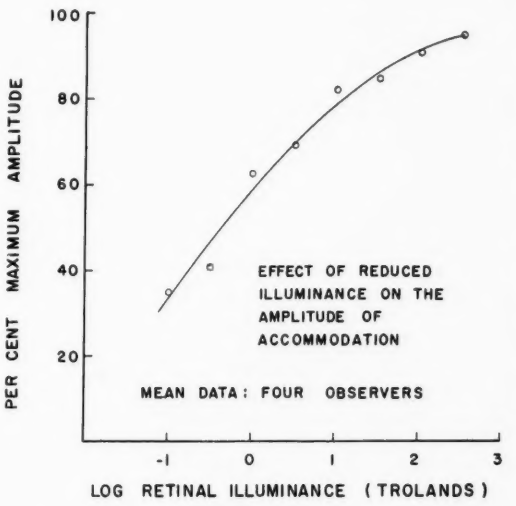
PER CENT MAXIMUM AMPLITUDE
EFFECT OF REDUCED ILLUMINANCE ON THE AMPLITUDE OF ACCOMMODATION
MEAN DATA: FOUR OBSERVERS
LOG RETINAL ILLUMINANCE (TROLANDS)

Figure 5.
The effect of reduced illuminance on the amplitude of accommodation. The maximum value obtained for each observer was set as 100%, and the other data related to this value.

the accommodation process. It is important to emphasize that all of these effects were obtained despite the fact that the measurements were made while the observer was looking through a

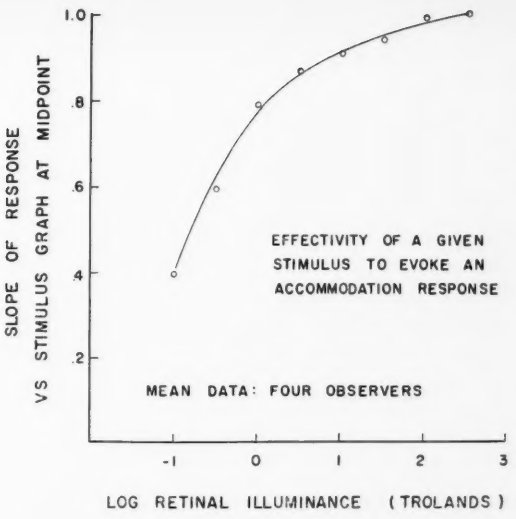
SLOPE OF RESPONSE VS STIMULUS GRAPH AT MIDPOINT
EFFECTIVITY OF A GIVEN STIMULUS TO EVOKE AN ACCOMMODATION RESPONSE
MEAN DATA: FOUR OBSERVERS
LOG RETINAL ILLUMINANCE (TROLANDS)

Figure 6.
Effectivity of a given stimulus to evoke an accommodation response for different levels of retinal illuminance.

small 2mm artificial pupil in the spectacle plane. Since the diameter of this aperture is considerably smaller than the smallest natural pupil size, this must mean that the effects cannot be attributed to factors dependent upon fluctuation in natural pupil diameter with illuminance. Therefore, for example, explanations based on change in the spherical aberration characteristics of the eye must be ruled out.[9] Furthermore, measurements were made of how much the accommodation of the eye actually changed and not merely on how much the accommodation stimulus was varied. This means that interpretations based on the variability of the depth of field with illuminance (owing to optical and/or perceptual factors) are quite unreasonable.

Is the reduced background illuminance itself an essential feature of these phenomena? It is possible to show that indeed it is not, for it can be demonstrated that the accommodative process of the eyes can function quite adequately even when the background illuminance is equal to zero. This effect is illustrated in Figure 7 which was taken in a completely dark field. All that was visible to the observer in this field was a small (approximately 2°) luminous cross, with infinitely thin limbs. This was sufficient to restore the far and near points of accommodation to virtually the same value obtained at the high levels of chart illuminance. It was possible, however, to obtain all the effects illustrated in Figures 4, 5 and 6 merely by reducing the intensity of the luminous cross. This was done by placing neutral density filters before the light beam producing the luminous cross. It is seen that a 3.0 density filter reproduced almost the same effect as the 0.5 troland level of Figure 3.

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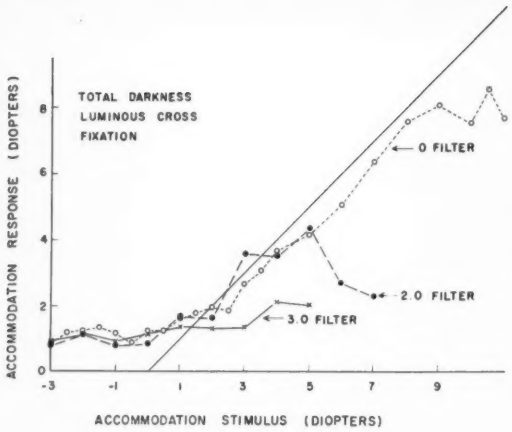

Figure 7.
The accommodative response for various accommodation stimuli at zero background illuminance. The fixation target is a small (2°) luminous cross with infinitely thin limbs. The various curves were obtained at different levels of luminance of the cross by placing neutral density filters before the beam which forms the cross image.

Hence, it is the visibility of the target against its background, rather than the absolute level of the illuminance of the background, which appears to be the important variable in these studies.[10,11]

It is not yet possible to compare the physiological changes in the above experiments with those associated with deleterious accommodation functioning produced by other means. Experiments which should make this possible are currently in progress. The matter seems most likely to be settled by studying what happens to the vergence movements of the eyes as the illuminance or contrast is reduced. It is well known that if the eye accommodates from far to near, the other eye (which is occluded) invariably moves nasalward. Experiments have described characteristics of such vergence movements in some detail.[12] A few measurements have also been made of this sort with variation in illuminance of the background. The procedure was simple. The eye position was recorded by amplifying the difference in voltage, recorded between EEG electrodes placed on the nasal and temporal canthi, as the eye moved.[13] The observer fixated the center of a black cross on a white background. The vertical limb of the cross was formed by a plumb line at the other end of the room while the horizontal limb was a piece of surgical gut stretched across a ring stand placed 16 centimeters from the eyes. Upon command the observer fixated the center of the cross but focused first the near (horizontal) limb, then the far (vertical) limb. Control experiments show that under these conditions only the occluded eye moved while the eye that was doing the seeing made no overt movement at all. Figure 8 shows some examples of the pen oscillograph records obtained from the occluded eye as the background luminance was varied. The smooth even movement of convergence following the first arrow (instruction to focus at "near") and of divergence following the second arrow (instruction to focus at "far") were the invariable results obtained in normal, young adults at high luminance levels. They appeared at the lower levels as well. Periodically there appeared also at the lower levels other records such as those illustrated in Figure 8. Features of the movements which appeared at lower levels were: inability to maintain eyes at the convergent position for the required time, reduced amplitude of the movement, interposition of irrelevant saccadic eye movements, and blinks. All of these features are illustrated in the records in Figure 8. They became more and more prominent as the light level was lowered.

We know very little as yet about these effects, or the factors which may influence them. One supposition is that they are in part reflections of identical innervations to the ciliary muscle and to accommodative vergence. Considerable evidence must be mustered before this guess can require much stature but one suggestion of its

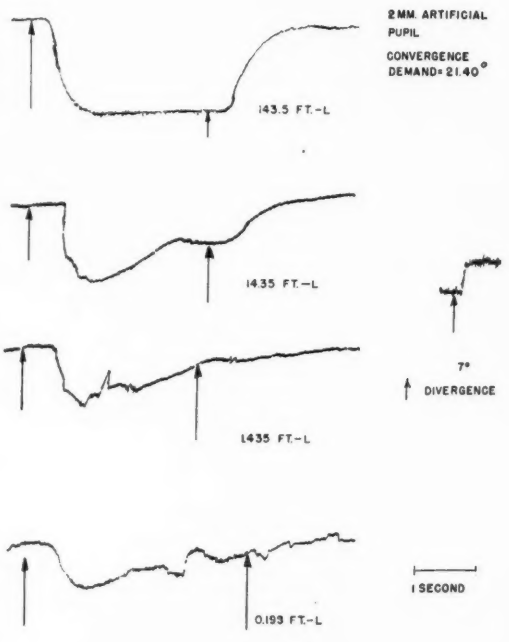

Figure 8.
Some records showing the accommodative vergence at different light levels. The first arrow in each series marks the stimulus far-to-near; the second the stimulus near-to-far.

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heuristic value is illustrated in Figure 9. The data compare the amplitude of accommodative vergence as measured in the way just described to actual measurements of changes in accommodation. These latter data were obtained by Campbell[14] by photography of the third Purkinge image as the eye accommodated to a minus six diopter lens as the luminance of a 1° test object was varied. Both sets of measurements were made with natural pupils. Whether the agreement between the two sets of data is anything but fortuitous, only a considerable number of further experiments can show. It does serve to point out, however, the possibility of using measurements of the accommodative vergence to study some of the other phenomena described in this report.

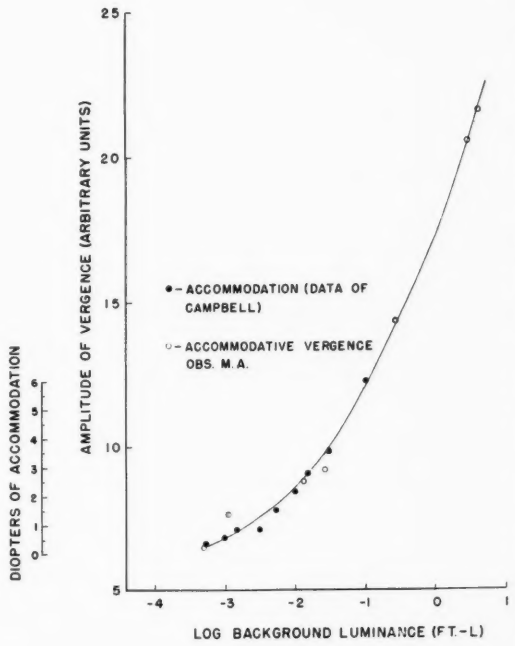
AMPLITUDE OF VERGENCE (ARBITRARY UNITS)
DIOPTERS OF ACCOMMODATION
●- ACCOMMODATION (DATA OF CAMPBELL)
○- ACCOMMODATIVE VERGENCE OBS. M.A.
LOG BACKGROUND LUMINANCE (FT.-L)

Figure 9.
Average amplitude of accommodative vergence as a function of luminance of the background (open circles) when the difference in the stimulus to accommodation was 6.14 d. The solid circles are measurements of the accommodation response to a 1° test object viewed through a minus six diopter lens at various levels of luminance of the test object. These latter measurements were made by Campbell (14).

Acknowledgements

Assisted by a grant from the Institute of Industrial Health, University of Michigan. Dr. Paul Ellen assisted in some early phases of these experiments. Prof. H. R. Blackwell gave many helpful suggestions.

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Tax Take

During an ordinary five-day workweek, an employee who earns $85 a week usually doesn't start making money for himself until Tuesday noon, estimates Tax Foundation, Inc. The pay for a day and a half each week goes for local, state, and federal taxes.

—From *Supervisory Management*, July, 1958.

XUM

Visual Comfort

IN THE PLANT

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Automatic presses, push-button controls, sequence machining and punch processing are all forms of the age of automation, but none of these are possible, nor can they function, without the human being. Yes, people are the all important ingredient of today's industrial society.

The rapid pace, high precision and keen competition in modern industry demand the utmost from every individual on the factory "team." Millions of dollars are invested in the plant for the most efficient machinery before a single dollar is returned on the investment. The final productive success, however, depends on how the "human machines" use the mechanical machines.

American industry has learned that people perform most effectively when their environment is comfortable, pleasant and geared to easy visual perception. Therefore, progressive factory planners consider heating and ventilation, noise control, light and decoration, air conditioning and even programmed music important environmental components of a well-designed factory. The lighting and decorative elements combine to form a "luminous environment."

Luminous Environment

The luminous environment consists of: 1. brightness from luminaires (lighting fixtures). 2. brightness (daytime) from windows, skylights, etc. 3. reflected light from floor, walls, ceiling, equipment, etc.

Direct Glare

Glare may be defined as any brightness within the field of vision of such character as will cause discomfort, annoyance, interference with vision, or eye fatigue. When the condition is caused directly by the source of lighting, whether natural or artificial, it is described as direct glare.

Most industrial applications call for either the direct or semidirect types of luminaires. Luminaires should direct some light to illuminate the ceiling or upper structure. The upward light reduces the "dungeon" effect of totally direct lighting and creates a more comfortable and more cheerful environment. Industrial luminaires are now available with upward components for fluorescent, mercury and filament lamps.

Top openings in luminaires will minimize dirt collection on the reflector and lamp because a draft path moves the dirt particles upward and through the luminaire to the outer air. This requirement for ventilation is another reason for selection of upward-component luminaires.

In selecting industrial lighting equipment, it will be noted that other factors lead to greater visual comfort:

1. Light colored finishes on the outside of luminaires to reduce brightness ratios between the outside of the luminaire and the inner reflecting surface and light source.
2. Higher mounting heights to raise luminaires out of the normal field of view.
3. Better shielding of the light source by deeper reflectors, cross baffles, or louvers. This is particularly important with high wattage filament or mercury sources and the higher output fluorescent lamps.

Brightness and Brightness Ratios

The ability to see detail depends upon the brightness contrast between the detail and its background. The greater the contrast, the more readily the seeing task is performed. However, the eyes function most comfortably and most efficiently when the brightnesses within the remainder of the environment are relatively uniform. Therefore, all brightnesses in the field of view should be carefully controlled. In manufacturing there are many areas where it is not practical to achieve the same brightness relationships as are easily achieved in areas such as offices. Between the extremes of heavy manufacturing and office light spaces, however, lie the bulk of industrial areas. Therefore, Table I has been developed as a practical guide of recommended maximum brightness ratios for industrial areas.

To achieve the recommended brightness relationships, it is necessary to select the reflectances

of all the finishes of the room surfaces and equipment, as well as to control the brightness distribution of the lighting equipment. High reflectance surfaces are generally desirable to provide the recommended brightness relationships and high utilization of light and they also improve the appearance of the work space.

TABLE I.
RECOMMENDED MAXIMUM BRIGHTNESS RATIOS

5 to 1	Between tasks and adjacent surroundings.
20 to 1	Between tasks and more remote surfaces.
40 to 1	Between luminaires (or sky) and surfaces adjacent to them.
80 to 1	Anywhere within the environment of the worker.

Many industries are painting machines with such colors that they present a completely harmonious environment from the standpoint of color. It is desirable that the background be slightly darker than the seeing task. It appears desirable to paint stationary and moving parts of machines with contrasting colors to reduce accident hazard by aiding identification. Table II lists the recommended reflectance values for industrial interiors, furniture, machines and equipment.

TABLE II.
RECOMMENDED REFLECTANCE VALUES

	Reflection Factor (%)
Ceiling	80
Walls	60
Desk & Bench Tops	35
Machines and Equipment	25 to 30
Floors	not less than 15

Reflected Glare

Reflected glare is caused by the reflection of high brightness light sources from shiny surfaces. In manufacturing processes this may be a particularly serious problem where critical seeing is involved with highly polished surfaces such as polished sheet metal, vernier scales and critically machined metal surfaces.

Reflected glare can be minimized or eliminated by using low brightness light sources or by orienting the work so reflections are not directed in the normal line of vision. Often it is desirable to use a large area, low brightness luminaire located in direct relationship to the work.

Color Quality of Light

For general seeing tasks in industrial areas there appears to be no effect upon visual performance by variations in color of light. However, where color discrimination or color matching are a part of the work process, the color of light should be very carefully selected. One example is in the printing industry where the Illuminating Engineering Society and the printing industry have created a standard color of light for appraisal of color work.

Color has an effect upon the appearance of the work space and complexions of personnel so the selection of the lighting system and the decorative scheme should be coordinated. Interior colors should be selected after appraisal is made under the same color of light as will be used in the area.

Silo-Fillers' Disease

Cases of silo-fillers' disease are not frequent but they can be fatal. A young man, strong and apparently healthy, was in a silo where he was tramping down ensilage or fodder. A fellow worker climbed up to see how he was getting along and found him lying on top of the ensilage, dead. In the summer season, the silo can become a lethal chamber. As a result of bacterial action, a high volume of carbon dioxide can result from fermentation of the contents of the silo. In the shredded cornstalk with its fodder and corn, the carbohydrate content undergoes atmospheric oxidation. Consequently, when the stalks are confined in a small, closed container such as the silo, oxygen is rapidly used up. In the silo, it is not unusual for carbon dioxide to reach 38%, while in the normal atmosphere it is only about one-fifth of 1%. Therefore, a person in an unventilated silo is exposed to the risk of succumbing to oxygen deficiency and dying of asphyxiation. The production of poisonous silage gas with dangerous concentration of nitrogen dioxide, depends on a combination of several unusual circumstances. A high content of nitrates in stalks of corn caused by prolonged dry weather and liberal use of nitrogen fertilizers are factors in producing poisonous gas. Prevention of silo-fillers' disease depends on the education of farmers in regard to the existence of this serious occupational hazard. —From *Oil City, Pennsylvania, Derrick*, August 29, 1958.

XUM

Visual Comfort

IN THE OFFICE

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Providing a means of assuring visual comfort in the office was a problem with which the Illuminating Engineering Society Committee on Office Lighting wrestled for over six years in preparing the 1956 IES Recommended Practice for Office Lighting. The basic problem was to provide a means of preventing the unwary from going astray without unduly restricting the experienced designer.

Brightness Ratios

For many years now, we have been placing considerable emphasis on achieving low brightness ratios in the visual environment. Brightness ratios must, however, be regarded as an objective or goal rather than a means of designing good lighting installations. Although it is possible to predict the brightness ratios that may be expected in a proposed installation, the necessary calculations are too laborious to be practical. Furthermore, the brightnesses that would be calculated are only the averages for large surfaces which would actually vary considerably in brightness over their entire areas. Brightness ratios by themselves also have the disadvantage of not recognizing the effect of the position or size of the areas of different brightness. The committee felt that a more practical method of achieving good ratios that would also go a little further in recognizing the effect of size and position would be to recommend the room surface and furniture reflectances and suggest luminaire brightness limitations.

Room Surface Reflectances

Table I shows the table of surface reflectances which the Office Lighting Committee recommends. It may be noted that in the first column of reflectances they are given as "center-point" values with tolerances. This conforms with the ASA method of presenting such data since the recommended reflectances for furniture and office machines have now been accepted as American Standards. (I would like to add at this point that this ASA acceptance of our IES recommendations is a real accomplishment, and we should take full advantage of it by encouraging the specification of furniture and machine finishes conforming with this table. There is usually no price premium for such finishes now that they are in more general use.) To prevent possible confusion in interpretation of the percentage tolerance, equivalent ranges of reflectance have also been provided in the same table. The use of the center point values as given in the first column of Table I is, however, to be encouraged.

Under certain conditions wall reflectances that are higher or lower than the limits of the 40-60% range may be satisfactory or even desirable. The ceiling finish may, for example, be carried down the walls to the level of suspended luminaires having a high upward component with increases in utilization of as much as 10% resulting. Conversely, a darker dado is sometimes employed on lower walls, but dados should have a reflectance of at least 25%. To provide the interior decorator with some freedom in creating a more colorful environment, it is suggested that small sections of walls may have reflectances higher or lower than the extremes if these areas are used for color accents and restricted to about 10% of the total wall area in the room. Entire walls having reflectances outside the recommended ranges should be used only with considerable discretion and by an experienced designer who recognizes the precautions that must be taken.

TABLE I.
RECOMMENDED SURFACE REFLECTANCES FOR OFFICES

Surface	REFLECTANCE "Center-point" Value and Tolerances	REFLECTANCE Equivalent Range
Ceiling Finishes*	.80+15%	80—92%
Walls	.50±20%	40—60%
Furniture	.35±25%**	26—44%
Office Machines & Equipment	.35±25%**	26—44%
Floors	.30±30%	21—39%

* Recommended reflectances are for finish only. Overall average reflectance of acoustic materials may be somewhat lower.
** American Standard Office Reflectances X 2.1.3, 1954, UDC 535.312:651.2.

Daylight Brightness Control

In many offices the fenestration makes up a large portion of the wall area and hence occupies much of the visual field. If a comfortable environment is to be achieved, it is essential that the brightness of this fenestration or of the view be controlled. Some of the current methods of controlling daylight brightnesses are: roll shades, venetian blinds, drapes, shade screens, awnings, louvres, low transmittance glazing and light directing glass blocks. Each method has advantages and disadvantages so that the actual selection of the medium to be used will depend upon the circumstances. Adjustable devices such as the first three listed can be regulated to suit requirements under different conditions, but there are often differences of opinion as to the best adjustment and necessary changes in adjustment to match changing conditions are often not made as promptly as they should be. Shade screens, awnings, or louvers can effectively shield excessive sky and sun brightnesses from view; but if neighboring buildings or ground areas will be seen through the windows, they may become sources of annoying high brightness when sun-lighted. Low transmittance glazing offers a good solution to the previously mentioned problem but also materially restricts the amount of daylight admitted. If glass blocks are used for daylight control, care should be taken to select a type that directs most of the daylight and sun brightness toward the ceiling.

Luminaire Brightness — Zones

Any discussion of luminaire brightness must first recognize that the direct and reflected glare zones entail different problems and hence require separate treatment. The direct glare zone is regarded as extending from approximately 45° from nadir to 87°, and the reflected glare zone extends from nadir to approximately 45°.

Direct Glare

The 1947 Office Lighting Practice recommends that the luminaire brightness in the 45°-90° zone not exceed 400 foot-lamberts. It should be understood that this recommendation is based upon maximum brightness, because maximum brightness has been used as a test criterion for many years and until recently was the only type of brightness data provided on photometric reports. It represents the brightness of the brightest square inch on the luminaire at the angle for which the data is reported.

To be significant, maximum brightness must be obtained in a photometric laboratory having a stable power supply and calibrated lamps. The measuring instrument consists of a metal tube 2 feet long with an aperture at one end and photocells at the other end, as illustrated in Figure 1. The aperture may be either square or circular, but it must have an area of one square inch. The inside of the tube is painted flat black. In use, this instrument is usually mounted on a movable rack arrangement so that when it is set at the angle for which data is required, it may be moved to explore the entire luminous surface of the luminaire without disturbing the angular setting. The maximum reading obtained for a given angle by means of this exploration is the maximum brightness for that angle.

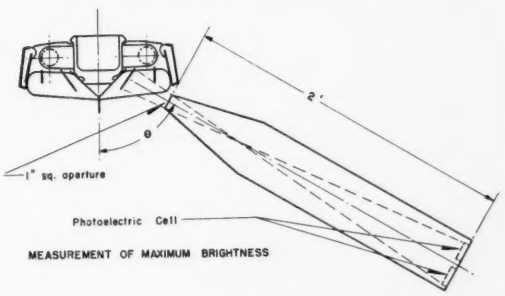

Figure 1.

An almost universal conclusion that has been drawn from the various researches on visual comfort is that direct glare is a function of the average brightness of the luminaires rather than the maximum brightness. It follows, therefore, that any recommendations regarding luminaire brightness should be based upon average brightness as the primary criterion. To quote the 1956 IES Recommended Practice for Office Lighting, "Although luminaire brightnesses have generally been specified, measured, and reported as maximum brightnesses (the brightest square inch at any given angle), investigations indicate that average brightness is a more pertinent criterion to use. The average brightness at any angle is determined when the candle power at the angle is divided by the projected area (in square inches) of all light generating and controlling elements of the luminaire that would be seen at that angle. Air space containing no light generating or controlling elements should not be included as part of the area. High reflectance (exterior) opaque side panels of luminaires having at least 15% of their total output in 110-140° zone may be included as part of the projected area, since in practice these side panels will be illuminated by light reflected from the ceiling to a brightness approximating that of a dense, diffusing side panel. End panels of luminaires must not be included in projected area since luminaires are frequently installed end to end, thus eliminating the end panels from most of the luminaires in the line of vision. This brightness will be in candles per square inch and may be converted

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to foot-lamberts by multiplying by 452."

An understanding of projected area is a prerequisite to understanding average brightness. We are concerned with obtaining these projected areas for crosswise and lengthwise viewing of the luminaire. The crosswise projected area at any angle is merely the luminaire length (in inches) times the projected width at that angle. Figure 2 illustrates the method of obtaining the projected widths of a typical luminaire at two angles, θ_1 and θ_2. It is most easily obtained graphically by projecting parallel lines from the luminaire at the viewing angle and measuring the distance between them. The endwise projected area is the product of the luminaire width by its projected length. Since no height is involved in the determination of projected length, the endwise projected area becomes the width times the length, times the cosine of the angle.

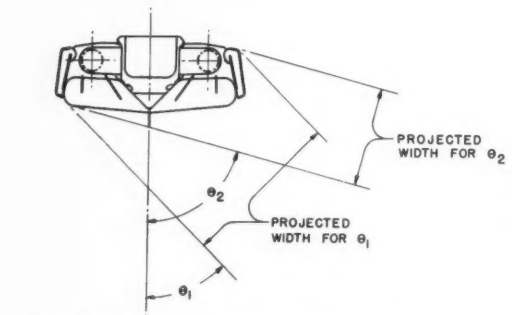
PROJECTED WIDTH FOR θ2
θ2
PROJECTED WIDTH FOR θ1
θ1
CROSSWISE PROJECTED AREA = LENGTH x PROJECTED WIDTH θ
ENDWISE PROJECTED AREA = WIDTH x PROJECTED LENGTH θ
= WIDTH x LENGTH x COS θ

Figure 2.

If desired, the average brightness data may be plotted on polar coordinate paper to obtain curves similar to candle power distribution curves. Their resemblance to candle power distribution curves may, however, be considered a disadvantage, and it is also sometimes difficult to read the values at high angles. This latter problem is particularly troublesome if the luminaire brightness approaches 0 at 90°.

Average brightness may also be plotted on rectangular coordinate paper as shown in Figure 3. It can be seen that this type of presentation permits values to be read with equal ease at all angles. For this reason, it is probable that this form of presentation will receive greatest acceptance. In fact, ETL is now providing this type of information in their latest photometric test reports except that they begin with 45° at the left side of the scale.

The use of average brightness as a primary criterion for preventing direct glare is almost obvious, but we now must determine what limitations on luminaire average brightness would be

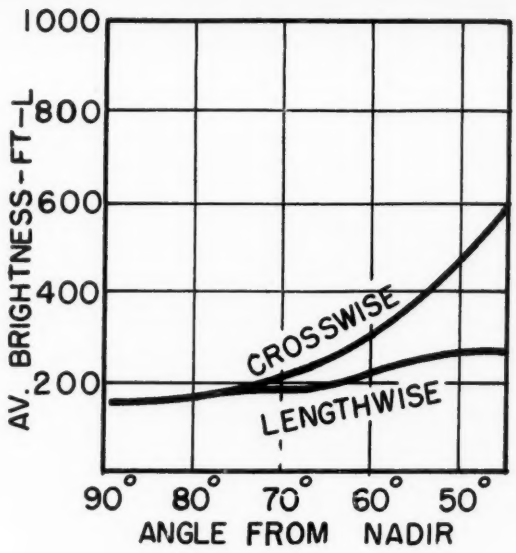

Figure 3.

fair and yet exclude equipment that would result in uncomfortable lighting installations.

After considerable analysis of available visual comfort data and experimentation with possible simplified systems, the Office Lighting Committee finally adopted the experimental laboratory data of Dr. Guth which shows that if you vary the position of a glare source from horizontal upward, the relative permissible brightness for the same glare effect varies in accordance with the curve shown by Figure 4.

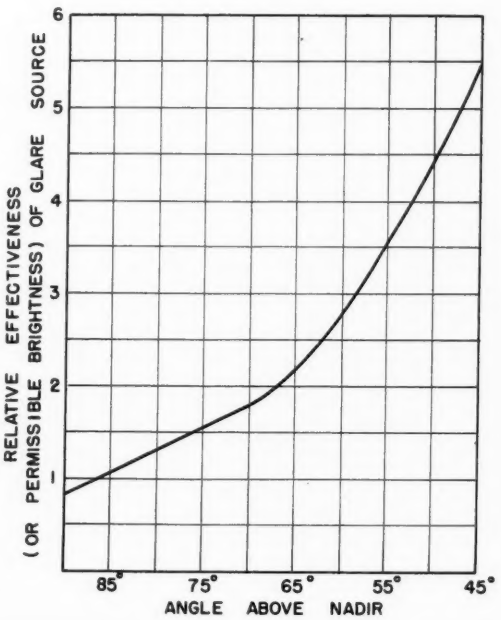

Figure 4.

This curve represents the maximum permissible nonuniformity in luminaire brightness. Other visual comfort studies, including the previous studies of the Committee, indicated that fluorescent luminaires having a uniform brightness of 250 foot-lamberts would not cause direct glare in 50 foot-candle installations. These studies took into account the effect of the size, number and positions of luminaires that would be employed for such an installation in a large room. Extensive studies to determine the equivalence of nonuniform sources to uniform sources indicated that Guth's curve for nonuniform sources should intersect the 250 foot-lambert uniform source line at 75°.

Figure 5 shows how the limitations for uniform and nonuniform brightness luminaires were combined to obtain an easily used, flexible set of recommended brightness limitations for the prevention of annoying direct glare. The Recommended Practice states "Direct glare should not be a problem in 50 foot-candle fluorescent lighting installations if ceiling and wall reflectance comply with Table I, and if luminaires used have crosswise and endwise brightness distributions within the limits established in Figure 5. The brightness distribution of the luminaires should be determined by plotting the average brightness at 10° angular intervals from 45-85°". It may be noted that in this figure the horizontal scale has been arbitrarily expanded so that Guth's curve appears as a straight line. This was done to permit the flexibility which is offered in the caption wherein it is stated that any straight line drawn through 250 foot-lamberts at 75° and lying between the two lines shown in Figure 5 may be used as the limitation line. In effect, this means that if a particular luminaire has a brightness at 85° that is slightly higher than the brightness shown on the sloping line of this figure, there must be a considerably greater reduction in brightness at 45° to compensate for this small increase at 85°.

The Practice further states, "Luminaire brightness limitations are more stringent for large luminaires and large offices than for small ones. The limitations suggested in paragraph (e) are based upon large luminaires such as fluorescent luminaires in large offices. Some luminaires (such as incandescent luminaires) commonly used in offices have projected areas at 0° that are in the order of one square foot; such luminaires may, therefore, have double the brightnesses indicated in Figure 5 and Table II. It is recognized that in small offices the brightness at the highest angles may not be significant and the brightness limitations for these angles could, therefore, be disregarded without impairing seeing comfort. Since many buildings include areas of mixed size or areas which are subject to change in size, and since most users would prefer to standardize on one luminaire type for all their office areas, it is suggested that the complete brightness limitations of paragraphs (e) and (f) be used for all offices."

Perhaps some examples would facilitate understanding the use of this figure. Figure 6 shows the crosswise and lengthwise brightness distribution of a two-lamp, 40 watt fluorescent luminaire equipped with a louver bottom providing 35° crosswise shielding and 25° lengthwise shielding. The luminaire has a rather higher central channel which can be seen at normal viewing angles and which results in a high brightness at 85°. The dotted line represents the brightness limitation line through 250 foot-lamberts at 75° which seemed to be most pertinent for this particular luminaire's average brightness distribution. It can be seen that the luminaire is satisfactory in all respects except for its crosswise brightness at 85°. This luminaire is a two-lamp 40 watt unit, so now let us look at the brightness distribution for a four-lamp 40 watt unit (Figure 7) equipped with a louver bottom providing 35° crosswise and

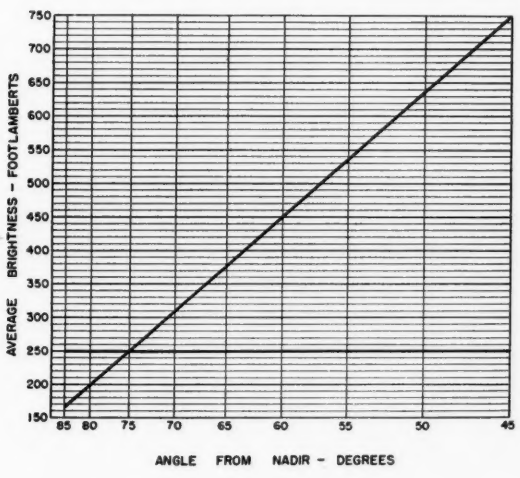

Figure 5.

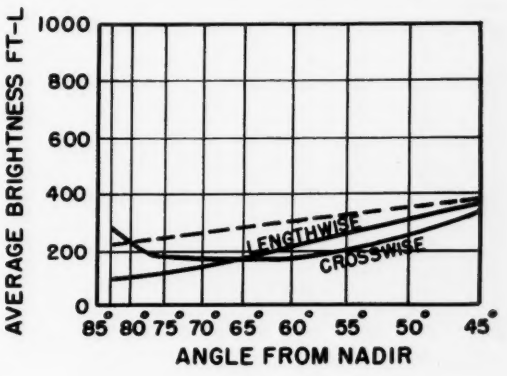

Figure 6.

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45° lengthwise shielding. We see here that the applicable limiting brightness curve shown by the dotted line has a somewhat steeper slope than the one shown previously. The effect of the 45° lengthwise shielding is quite apparent in the brightness distribution plot shown.

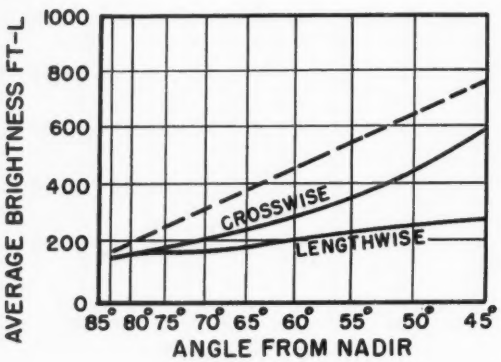


Figure 7.

For those who prefer tabulated data to curves, the RPOL also includes Table II with the instructions that "Any luminaire whose average brightness at each of the angles in the table does not exceed the brightnesses in any single column of the table will comply with intent of the limitations described in paragraph 3.3.2(e)." This table is merely a tabulation of the brightness values that would be read from a series of limitation lines drawn through 250 foot-lamberts at 75°.

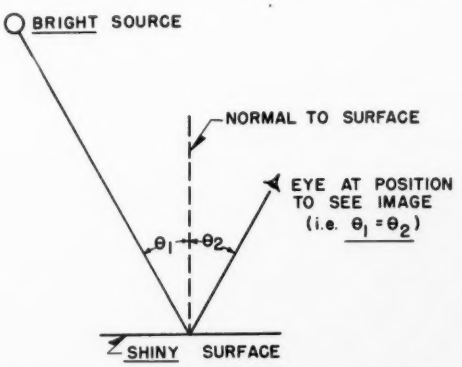
TABLE II.
ANY LUMINAIRE WHOSE AVERAGE BRIGHTNESS AT EACH OF THE ANGLES IN THE TABLE BELOW DOES NOT EXCEED THE BRIGHTNESSES IN ANY SINGLE COLUMN OF THE TABLE WILL COMPLY WITH THE INTENT OF THE LIMITATIONS DESCRIBED ABOVE

Angle	Average Brightness (Foot-lamberts)								
85°	250	240	230	220	210	200	190	180	165
75°	250	250	250	250	250	250	250	250	250
65°	250	265	280	295	310	325	340	355	375
55°	250	285	315	350	385	415	450	480	535
45°	250	310	365	420	480	540	600	660	750

To quote the Practice again, "The use of average brightness as the primary criterion for direct glare is based upon the assumption that office workers seldom raise their line of sight above horizontal. If the eyes are directed at the luminaires themselves, the effect of nonuniformity in their brightness distribution is more evident. Furthermore, marked nonuniformity may prove distracting. To prevent nonuniformity in luminaire brightness from becoming a source of annoyance, there should be a limit on the ratio of maximum to average brightness. Ratios should be checked at each angle where the maximum brightness occurs in the 45-60°, 60-75°, 75-87° zones. (Brightnesses and angles greater than 87° are not in view, even in the largest rooms.) This ratio of maximum to average brightness preferably should not be more than three to one, and in no case should it exceed five to one nor should the maximum brightness for a given angle ever be more than three times the average brightness as shown for that angle on the sloping line in Figure 5. The maximum brightness shall be the laboratory measured (by photoelectric means) brightest square inch (square or circular)." In effect, this means that we would prefer the maximum brightness of a luminaire never to exceed the average brightness by more than three times, but if the average brightness is very low, a maximum brightness that is not more than five times the average might be permissible. Thus a luminaire having an average brightness of 300 foot-lamberts at 45° might have a maximum brightness of as much as 1,500 foot-lamberts at that angle without being objectionable. On the other hand, if the luminaire had a high average brightness of 700 foot-lamberts at 45°, a maximum brightness of 3,500 foot-lamberts would not be acceptable because this would exceed three times the 750 foot-lamberts average brightness shown by the sloping line at that angle.

Reflected Glare

Up to this point, we have discussed only the problem of minimizing direct glare. Let us now consider the reflected glare problem which may be regarded as a three-headed monster. It occurs when shiny surfaces reflect images of bright sources toward the eye as shown in Figure 8.



THREE FACTORS CAUSING REFLECTED GLARE

Figure 8.

Thus we see that there are three contributing factors — the shininess of the surface, and angular relationship which results in the reflection being directed toward the eye, and a source or luminaire whose brightness in the 0-45° zone is of such a value that its reflection in a shiny sur-

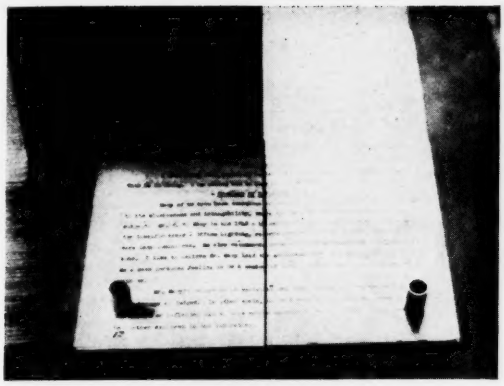


Figure 9.

face will be annoying. Since there are three contributing factors, there are three possible solutions.

There are also two kinds of reflected glare, for it may occur within the task itself or in the area immediately surrounding the task. When it occurs within the task, it may result in a reduction in visibility such as you see in Figure 9. In this figure, the left-hand portion of the task is so illuminated that there is no reflected glare, while the right-hand portion is so lighted that maximum reflected glare from a medium brightness source occurs. The reduction in visibility resulting from the reflected glare condition is very obvious. We must admit that there is not much opportunity to reduce the task shininess here, but it is sometimes possible to make some improvement in a task. We can, for example, encourage the use of low gloss ink instead of pencil.

We might, however, be able to solve this problem by checking the angular relationships between the luminaire, the task and the eye. Existing installations can be checked by means of a mirror. When planning an installation, the fact that the angle of reflection will equal the angle of incidence can sometimes be used to determine whether or not a luminaire in a proposed location will cause a reflected glare problem.

It should be recognized, of course, that we seldom notice visibility reduction as bad as that shown because we involuntarily adjust the angle of the task or its location to prevent it. Furthermore, the addition of nonglaring illumination reduces the veiling effect of the glare source. That is, when we design installations so that the illumination on the task comes from several different directions, we can reduce the veiling effect produced by sources that are so located that they cause reflected glare.

Our final possible solution to the reflected glare problem is to limit the brightness of the luminaire. Studies of reflected glare have indicated that it is the maximum rather than the average brightness with which we must be concerned in the reflected glare zone. There has been very little research upon which to base luminaire brightness recommendations for the reflected glare zone, but we do know from experience that "luminaires and fenestration having maximum brightness in the order of 350 footlamberts and less have generally proved to be satisfactory." (quoted from the RPOL).

In Figure 10 we have an example of reflected glare in the area immediately surrounding the task. Surprisingly enough, measurements show that the brightness ratio of such reflections with respect to a task are not excessive although in this instance the low reflectance of the desk top itself does result in an undesirable brightness ratio between reflected luminaire image and the adjacent desk surface. The main problem, however, seems to be the distracting effect of the reflection and the fact that it requires the eye to reaccommodate. If the eye is focused on the task at 14 inches as shown in Figure 12 and

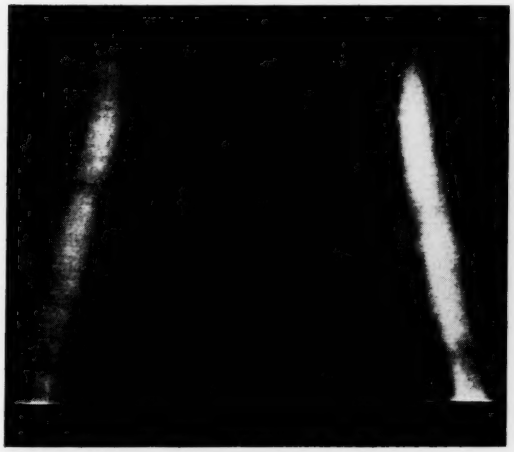


Figure 10.

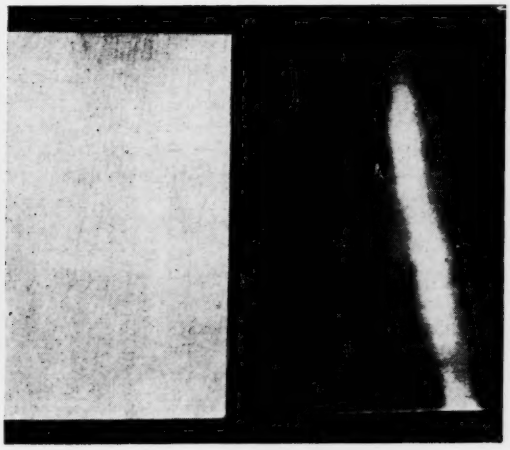


Figure 11.

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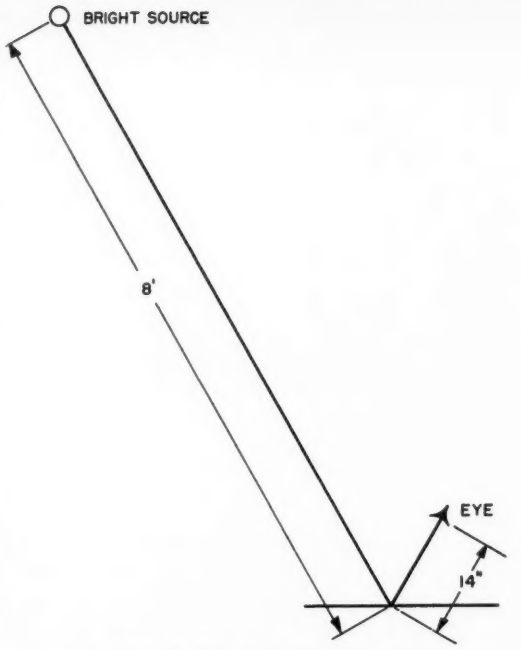
it is distracted so that it is directed to the nearby reflection of a glare source in the desk top, it will try to focus to obtain a sharp image of the reflection. The focusing distance will, of course, be the sum of the distance from the eye to the reflection plus the distance from the reflection to the glare source. This involuntary accommodating action brings eye muscles into play and can result in fatigue if the action is repeated frequently over prolonged periods of time.

Here again we have three possible solutions. The simplest and most obvious solution is to use the recommended high reflectance matte surfaces that were discussed with Table I. Figure 11 is the same desk top shown in Figure 10 except that the right-hand portion has been covered with a linoleum having a high reflectance, matte surface. The very considerable progress that has been made in the use of such finishes on office furniture and business machines should be noted at this point, and this progress is largely the result of the efforts of members of the IES Office Lighting Committee. A second solution is to so locate the luminaires with respect to the task that all reflections will be away from the eye. This is most easily accomplished in a private office where the luminaires may be located over the work area so that reflected glare is minimized and maximum illumination is obtained on the work area. Our third solution is, of course, to limit the brightness of the luminaire.



REFLECTED GLARE MAY REQUIRE EYE TO ACCOMODATE FOR GREATER DISTANCE TO SOURCE

Figure 12.

Conclusion

There is much that we still have to learn, before a completely satisfactory method of designing for visual comfort in the office can be developed. Meanwhile, however, we now have in the 1956 IES Recommended Practice for Office Lighting a usable and workable method that we should all be using as a means for designing pleasant, comfortable environments.

The Doctor Explains to the Patient

Detailed explanations of the basic elements of an illness, given unhurriedly and sympathetically, have become additional "tools" of the modern doctor. Discussions between the doctor and his patient regarding the probable duration of the illness, how therapy is expected to be effective, and its effect on the patient's manner of living — serve several purposes. Misunderstanding is avoided, and the patient's fullest cooperation is more likely to be obtained; anxiety, an almost constant factor in organic illness, is alleviated; a good physician-patient relationship is established by the physician's obvious interest; the doctor's sympathy, understanding, and patience become powerful therapeutic agents; and severe nervous reactions are less likely to occur. "Such an approach may require an attitude different from what the physician learned in medical school, when emphasis, for the most part, was on the particular ailment rather than on the patient with the ailment," the article points out. "Today, patients take scientific diagnosis and treatment for granted, want personalized attention, and expect consideration of themselves as individuals."

—From *Therapeutic Notes.*

Maintaining Lighting Levels in the Office

W. A. STANNARD, General Lighting Sales Supervisor
Consumers Power Company, Jackson, Michigan

The purpose of lighting is to provide efficient and comfortable seeing as an aid to office operation and the conservation of vision. It is important, therefore, to analyze the controllable factors which contribute to seeing; the task, the lighting and the environment.

Seeing Tasks

In modern office operations, the eyes are used at close range for severe visual tasks such as reading duplicated material, handwriting, penciled stenographic notes, typing and fine print. The visibility of such work is often poor and more attention is being devoted to its improvement.

Through improvements in the visibility of objects, the waste of human resources can be materially reduced. Eyesight, energy, life, health and other human resources are conserved in this way. Visibility is controllable beyond the threshold limitations of internal functions, for it depends upon many external factors associated with the object or visual task. In reading for example, the type, ink, paper and printing are fixed as far as the reader is concerned, but they are controllable by the printer. Usually, the reader can exercise partial or complete control over such important factors as quantity and direction of light. The reader is often free to refuse to read books of fine print. So it is with most visual tasks, and no person possessing eyesight is entirely free of the responsibility of improving visibility.

Scientific research has established an important correlation between visibility and nervous muscular tension. Ease and certainty of seeing are closely related to visibility. When visibility is high, the task is easier than when it is low.

From the viewpoint of visibility, objects vary from simplicity to extreme complexity. All objects are relatively simple when merely perception is involved. When they must be recognized, their complexity becomes evident. In many cases, such as driving along a highway at night, one is usually more concerned with perceiving an object on the roadway than in recognizing it. Often safety is well served merely by perception. However, in most serious visual tasks recognition of critical details is necessary.

A series of familiar objects increasing in complexity is represented by a circular dot, the letter "O", the letter "C", a short word and a long word. The critical details which must be seen, if simple objects are to be recognized, usually are obvious. In a short word, the important ones are those in the letters most difficult to recognize. That the individual letters of a word, which we may seemingly recognize as a whole, are important is proved by the conspicuousness of typographical errors. Recognition of long words and of sentences involves eye-movements and other factors which need not be considered for the present. However, when recognition is traced down to fundamental details, it is found that there are four factors of primary interest:

Size of a simple object, or of the critical detail of a complex one, upon which recognition depends. The size of an object's image on the retinas of our eyes is the important factor, not the actual size of the thing in space. We are seldom concerned about items so small as to be invisible, but there are many instances in which we would do well to increase the size of work details and orient the work so that the visual size would be in full proportion to the actual size. For example, 10-point type viewed at 45° is no larger in visual size than the smaller 7-point that is viewed straight on.

Contrast in brightness, or color, between an object and its background. To be visible a thing must have light on it and must stand out from all the things around it. This means that the light from an object must somehow be different from the light coming from surrounding objects. The light may differ in amounts, in color, or both, but there must be contrast in brightness or color if we are to see.

Brightness of the object or of its background. The brightness of an object is a measure of the light coming from a unit area. For most office surfaces, the brightness value (foot-lamberts) is equal to the illumination level (foot-candles)

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multiplied by the reflectance. With more light, the brightness of tasks is increased and seeing tends to be faster, easier and more accurate. These benefits do not accrue without limit but ideal levels in this regard are higher than those recommended or employed currently.

Time available for recognizing the object. It takes time to see. Assume an employee has been looking about the office to get a moment's relaxation from the burden of seeing. As the view goes back to the work, the eyes must converge, focus for near distance and readapt if the work brightness is different from that about the room.

The time required for seeing is often very important where safety is involved. Many examples in factories, on streets and highways and elsewhere are excellent testimonials of the value of high visibility in reducing the time to see, when split-seconds are as long as eternity.

Recommended Levels of Illumination

The high levels of illumination produced by natural daylight are desirable for many seeing tasks. Before the development of modern light sources, many severe visual tasks had to be performed in daylight hours because of the low levels of illumination provided by artificial illuminants then in use. The illumination intensities which were considered to be good practice in past years were largely determined by the light sources then available. Present day practice recognizes that the foot-candle levels now recommended do not represent the ultimate in seeability. They do, however, represent practical values which may readily be obtained by means of existing light sources and equipment.

Our eyes can see most office tasks under an amazingly small amount of light. Often a fraction of a foot-candle is sufficient. Our eyes are of little direct value in setting specifications. Certain laboratory researches give good evidence that optimum levels for a majority of office tasks are in the range of 400-500 foot-candles.

The IES "Recommended Practice of Office Lighting," the NOMA "Office Lighting Standard" and the "American Standard for Industrial Lighting" currently recommend from 30 to 50 foot-candles, the amount being higher for the more severe or demanding office and drafting room assignments. There are many installations throughout the country of well over 100 foot-candles giving satisfactory results today.

Quantity Requirements

These recommendations are commensurate with the difficulty of the various group of seeing tasks and the current general cost of lighting.

Higher values than those given are desirable and will under proper environmental conditions result in more efficient visual performance.

The values should be maintained in service through proper cleaning of lighting equipment, replacement of depreciated or failed lamps and maintenance of room surfaces. Initial values will have to be greater by a percentage sufficient to compensate for the depreciation expected.

The recommendation should be provided on the work surface. Most office tasks are on a horizontal work plane but many seeing tasks are on vertical or nearly vertical surfaces. Illumination calculations determine the average horizontal work plane level, but the vertical illumination will be in the order of one-third to one-half the horizontal work plane illumination level.

TABLE I.

	Foot-candle Current Recommended Practice On Work Surface
Difficult Seeing Tasks	50
Involving:	
a. Discrimination of fine details such as 6-8 point type	
b. Poor contrast	
c. Long periods of time	
Such as:	
Auditing, accounting and tabulating	
Business machine operation	
Bookkeeping	
*Drafting	
Designing	
*Transcribing from pencil notes or poor reproduction	
Ordinary Seeing Tasks	30
Involving:	
a. Discrimination of moderately fine detail such as 8-12 point type	
b. Better than average contrast	
c. Intermittent periods of time	
Such as:	
Office work except for work coming under "Difficult Seeing Tasks" above	
Conferring or interviewing where reading or reference to seeing tasks of some severity is involved	
*Active filing	
Mail room work	
Reception room tasks (on desks)	
Casual Seeing Tasks	10**
Such as found in:	
Inactive file rooms	
Discussion and conversational areas where no reading is involved	
Stairways and escalators	
Washrooms and other service areas	
Elevators	
Hallways and corridors	
Passageways	

*Likely to be on vertical or nearly vertical surface.
**Or 20% of illumination in adjacent area, whichever is greater.

Lighting Systems for Office Areas

General Office: Most general offices are moderate to large sized areas in which there is no protection by reason of size limitations from lighting units being located directly in the field of view. In these areas, it is particularly important to avoid units of the general diffuse type. At the same time, it is in the general office that seeing is most difficult and most nearly continuous; for this reason quality and seeing comfort never should be compromised.

Spacing of luminaires from the side and end walls of an office has often been of concern to the lighting engineer and, of course, to the office personnel working under these lighting fixtures.

Our practice in this connection has been guided by the recommendation in Section nine, page 17, of the IES Lighting Handbook, second edition:

"The distance between luminaires and the wall should not exceed one-half the distance between the luminaires. Where desks or benches are along the wall, the distance between luminaires and wall should not exceed one-third the spacing between luminaires. Where direct and semidirect luminaires are used under such conditions, the perimeter of luminaires should be carefully located to avoid shadows on the work from the worker."

To consider the first part of the statement, "the distance between luminaires and the wall should not exceed one-half the distance between luminaires," this specification means that with luminaires spaced 10 feet on center, the luminaire spacing from side walls should be five feet. This spacing recommendation, however, is often applied to offices before the layout of office equipment is known.

The balance of the recommendation, taken literally for all circumstances, could be improved. "Where desks or benches are along the wall, the distance between luminaires and wall should not exceed one-third the spacing between luminaires. Where direct and semidirect luminaires are used under such conditions, the perimeter luminaires should be carefully located to avoid shadows on the work from the worker." Assuming a 10 foot spacing between luminaires, one-third of this spacing is three feet, four inches from luminaire to wall. With some placement of furniture and equipment, this spacing also causes shadows.

Illuminating engineers will agree with the statement, "Where direct and semidirect luminaires are used under such conditions, the perimeter luminaires should be carefully located to avoid shadows on the work from the worker." However, direct-indirect and general diffuse luminaires should also be included in this category. In order to assure proper location of luminaires adjacent to side walls, the following specific lighting recommendations are offered: Spacing between luminaires and wall should be two feet, six inches.

This spacing permits rearrangement of desks with maximum utilization of illumination. For example, the conventional desk is five feet long by two feet six inches wide; therefore, in an application where desks are placed against the wall, with the person performing the work facing the wall, the luminaires spaced two feet six inches from the wall would be centered over the leading edge of the desk.

Careful consideration should also be given for specifying that the end of luminaires be spaced as close as possible to walls. To assure satisfactory uniform illumination and minimizing of shadows, the ends of the luminaires should come within six inches to being one foot from the wall.

The basic lighting plan for office lighting should be a design that will include proper spacing of luminaires to provide a pattern of lighting to fit any arrangement of office desks and equipment.

Private Offices: Private offices are usually of moderate or small size. Usually eight by 15 feet or 12 by 15 feet. Either direct or indirect lighting can be applied satisfactorily since much of the lighting equipment on the ceiling itself is generally not within the visual field. Smaller rooms, it must be pointed out, accentuate the inefficient utilization of indirect lighting. The arrangement and orientation of furniture in the private office is fixed and permits the placement of direct lighting equipment to minimize both direct and reflected glare. A lighting system may literally be designed for and around the office desk and furniture.

In offices of moderate or small size, other factors of comfortable lighting must not be violated. Not only is it necessary to provide satisfactory illumination for the occupant at the point of work, but sufficient brightness on walls, floors and other areas is necessary to avoid high brightness ratios with the work. The use of dark paneled walls, desks and floor coverings are not conducive to comfortable seeing, and higher reflectance materials are available with equal character, taste and decorative value.

Drafting Rooms: The lighting requirements of drafting and graphic art work are about the highest encountered in offices. The visual demands are severe, requiring continuous, close attention to details of generally not better than moderate visibility. Glossy surfaces on paper, cloth and instruments are too often present, and are ever potential causes of reflected glare. The contrast between the work detail and its background may be very poor, as, for example, when tracing a faint blueprint or worn pencil drawing. Shadows along the drawing edge of the T square or a triangle may materially reduce visibility, or strong multiple shadows from the drawing instruments or the draftsman's hands may prove annoying.

Indirect lighting remains the reference criterion of lighting for drafting rooms. Over most of the illumination range employed today, direct-view quality is excellent, and shadows and reflected glare complaints are minimized.

Indirect systems are, in effect, direct lighting. The indirect aspect is but incidental to making the ceiling a large, diffuse, nearly uniform brightness source of light. The same effect is ac-

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complished in louverall and luminous ceiling systems. With louverall, the louver grids provide direct view shielding and low-diffusion material may be placed above to obscure lamp images. On the other hand, the projecting acoustic wedges generally used with luminous ceilings act like beams to provide direct view shielding.

No one system can be recommended to the exclusion of all others for each has characteristics that may or may not match the requirements of a given application. The performance of each should be evaluated first as to whether it will sufficiently provide lighting to meet the basic needs of a comfortable environment in the office. Secondly, the appearance of the equipment in the completed installation should be in keeping with the architectural and decorative design of the office.

To achieve a comfortable brightness balance in the office, it is desirable and practical to limit brightness ratios between areas of appreciable size from normal viewpoints as follows:

One to one-third between task and adjacent surroundings.

One to one-tenth between task and more remote surfaces.

Twenty to one between luminaires (or fenestration) and surfaces adjacent to them.

Forty to one anywhere within the normal field of view.

These ratios are recommended as maximums; reductions are generally beneficial.

Standards for Selecting Luminaires

It is recommended that louvered fixtures be selected which provide 45° shielding parallel to line of sight and 34° to 45° perpendicular to the line of sight. At these limiting angles the maximum average brightness should not exceed 750 foot-lamberts.

Direct glare zone limiting curves are given in complete detail in the "Recommended Practice for Office Lighting" published by the Illuminating Engineering Society, 1860 Broadway, New York City, 23. All brightness data and reflectance values covering glass, metal, plastic panel luminaires and wall to wall luminous ceilings are to be found in this publication.

I would like to inject at this point a word of caution in the specifying of luminaires. In selecting fixtures for ceiling mounting, the National Electric Code, 1956 edition, specifies the following: "Fixtures having exposed ballasts or transformers shall be so installed that such ballasts or transformers shall not be in contact with combustible material. Where fixtures are to be installed on combustible low-density cellulose fiberboard, the fixture shall be approved for this condition or they shall be mounted not less than 1½ inches from the surface of the fiberboard."

What Constitutes Planned, Effective Lighting for Modern Offices

Well planned lighting and associated seeing aids can minimize fatigue and increase office productivity. High comfort and good appearance are essential to an effective office lighting system. The factors that make a lighting system comfortable or uncomfortable to occupants of an office are well known to the lighting engineer. The factors which must be evaluated for each installation are the brightness of the lighting units or systems, their visual size, their position or location in the visual environment and the general brightness level of the whole environment.

Gaining a balanced brightness environment can be a major problem in any office. But there are some established rules and it is only common sense to use them if a high standard of seeing comfort is to be realized. They are:

1. Control window glare.
2. Lighten desk tops. For good balance, tops ought to reflect about one-third of the light falling upon them. Reflectance must be in the 25% to 45% reflectance range.
3. Lighten walls and ceiling. Reflectance specifications are: Ceilings 80% to 90%. Walls 40% to 60%.
4. Furniture and machine reflectances. Desk sides, file and office machines should have a reflectance value in the 25% to 45% range.
5. Floor finishes are important too. Select materials in the reflectance range of 20% to 40%.
6. Woodwork and trim such as door and window frames also should be light if they are not to attract undue attention. Suggested range of reflectances is 25% to 45%.

Economic Factors

Good lighting is a profitable investment. It saves time, money and workers' energy. An investment in a planned seeing environment need produce only a small increase in employee performance to be profitable.

The annual cost of a typical office operation is about 30 dollars per square foot.

Of this amount-

Space accounts for about	$ 2.50	8½%
Services and supplies	1.50	5 %
Furniture and machines	.75	2½%

Of the balance- $25.25

Lighting accounts for about ...	.25	4/5½

But-

Salaries and Wages Total	25.00	83⅓%

Every office spends something for light; about 25 cents per square foot annually for the typical office. This is 1% of payroll, or an even smaller fraction of total office cost.

Reinvesting this amount will be profitable if employee effectiveness increases by 1% to 2%. Each percent increase is worth 25 cents per square foot per year. Increases of 5% to 10% are common.

Benefits of Planned Office Lighting

The results to be expected from well-planned office lighting include: increasing employee efficiency by saving working time, cutting down errors, reducing absenteeism, boosting production and reducing eyestrain and fatigue; improving employee morale; promoting better housekeeping; training employees faster; increasing property value; creating prosperous environment; helping prevent costly accidents; improving public relations; attracting new employees; helping to retain present employees; promoting confidence in business; increasing pride of ownership; effecting efficient utilization of space; helping older, more experienced employees with failing vision.

The benefits to be derived indicate that planned lighting contributes not only to workability but also to the livability of offices. It is reassuring to have practical, positive proof data. Recent studies by agencies of the Federal Government have provided such evidence. Statistical analyses of results were conducted by the U. S. Public Health Service and are available upon request.

Cramps of the Vocal Cords

Professional singers, announcers, lecturers and others who use their voices for their livelihood are sometimes striken with a sudden painful, paroxysmal, short-lived muscular contracture which affects the fibers, one or more of the laryngeal muscles, or other muscles normally used in vocal production. This is accompanied by transient aphonia. Pradillo in 1950 wrote that these voice cramps might be similar to athletic cramps, and they were described later by Tarneaud. Because laryngeal muscle has the power to vibrate as well as to contract, its metabolic requirement of oxygen and nutriments is increased with the development of its functional activity. In this respect it may be compared to cardiac muscle, which vibrates in similar fashion and also requires more oxygen than other muscle fibers. In a recent article Pradillo states that the etiology and pathogenesis do not differ from those of other cases of cramp such as those occurring in swimmers and writers, and nocturnal cramp. He has interviewed many members of vocal professions to obtain his information. Vocal cramps seem to be more frequent after the age of 40, and the author believes the determining factor in their cause to be vocal fatigue. The cramps occur after long periods of use of the voice. In the anaerobic phase of muscle metabolism the carbohydrates pass through the transformations from glycogen — glocose — glucose-6-phosphate — pyruvic acid — lactic acid. Intense muscle activity leads to the formation of large amounts of pyruvic acid, which deranges the phases of metabolism that follow. Incomplete combustion in turn brings about oxygen debt. Such results of vocal fatigue are probably common among such voice professionals as singers undergoing the excessive strain of long and arduous rehearsals. According to Pradillo, the pain of vocal cramp must be attributed to local anoxia, since it is quite comparable to the pain of angina pectoris. Other physiologic conditions can be involved in the causation of cramps, including hormonal and glucide disturbances as well as uricemia and diseases of a general character. Inflammation and the irritation centers affected by reflex mechanisms have been considered as causes of muscle cramps, and psychoneurosis is also implicated as an etiologic factor. However, even though the cause has not been definitely established, it can be assumed that anoxia has a major role. Vocal fatigue sufficient to cause cramping of the cords is followed by extremely severe pain, usually on the sides of the larynx, and phonation becomes impossible. The condition persists longer than one minute. Massage may relieve the pain and enable the performer to continue in good voice, but the cramp may return at once or after several days, when vocal exercise is resumed. Cramps of the vocal cords should not be confused with other phonetic impairments such as "trac" (vocal anxiety), neurovascular monochorditis, *coup de fouet*, and "crac." In all the cases studied by Pradillo, fatigue has been the causative factor in the development of vocal cramps of the professional voice, and upon investigation it can be demonstrated that the frequency of vocal cramps, like that of other types, is considerable.

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Light AND COMFORT

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Providing lighting for seeing involves more than merely illuminating a task. The brightnesses of all areas within the visual field and the relationships among them contribute favorably or unfavorably to the seeing conditions in a visual environment. They may affect the visibility of a visual task, or their effects may be less obvious and result in decreased ease of seeing. The results of many investigations have indicated that the brightness relationships within the central visual field determine directly the visibility of any specific object or task. On the other hand, the brightness relationships in the surrounding field and between the central and surrounding fields usually have an indirect, or less obvious effect upon visibility and visual performance. However, the latter do determine directly the comfort of the visual environment. That is to say, the quality of lighting may be such as to have little or no significant effect upon visibility or visual performance but may result in extremely uncomfortable or distracting seeing conditions.

Thus, the ultimate objective of lighting practice is to provide brightnesses in the entire visual environment which produce the most satisfactory seeing conditions in terms of visual performance, ease of seeing, safety and comfort.[1]

Brightness and color are primary factors in perception and brightness contrast is very generally of major importance in the visibility and recognition of details of objects. In other words, within a visual task brightness contrast is a favorable factor is seeing. However, when the brightness of the central field or visual task differs greatly from that of the surround field, unfavorable effects of seeing are produced. In this respect, brightness contrast is an unfavorable factor in seeing.

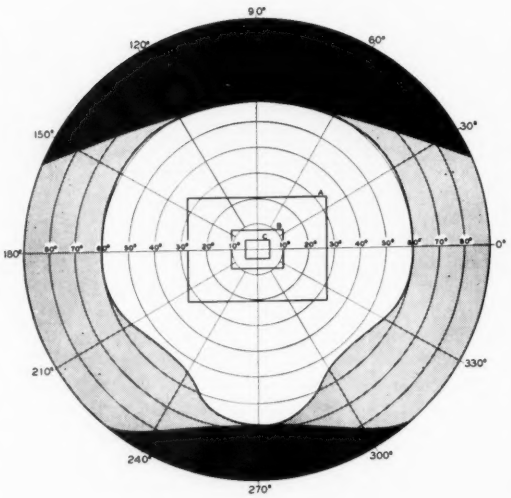

Figure 1.
A diagrammatic representation of the visual field. The unshaded area represents that portion of the field seen by both eyes. The shaded areas (right and left) represent portions seen only by the right and left eyes, respectively. The rectangles represent several sizes of task areas.

A brief study of Figure 1, which represents schematically the entire visual field, will emphasize the importance of all portions of a visual environment. The white central area is that part of the field which can be seen simultaneously with both eyes. The shaded areas on the left and right can be seen only by the left and right eyes, respectively. At the center of the visual field is a small area of about one degree in which we do our accurate seeing of fine detail. The entire field extends horizontally more than 180 degrees and vertically almost 130 degrees. In the outer portion of the visual field we do not see objects or colors with any degree of definiteness. However, we do see changes in brightness or movements in this outer or peripheral region.

The importance of the various portions of the visual field can be emphasized by considering the relative areas involved. The three rectangles indicated on Figure 1 represent several sizes of task areas. The largest rectangle, A, corresponds to a book or magazine held at normal reading distance. This particular task occupies about 15%

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of the visual field. If the task area is very small, such as that represented by rectangle C, it may occupy less than 1% of the visual field. In both of these examples it is obvious that the area surrounding the visual task is physically large. Its size makes it impossible to ignore.

It must be emphasized that seeing is a dynamic activity of human beings. The eyes do not remain fixed upon a single point but view all parts of a task and even areas beyond the more or less definite limits of the task. For example, again referring to rectangle A of Figure 1, part of the time a worker may be looking near one of the corners or edges of the rectangle. This brings close to the line of sight what previously may have been considered to be a relatively remote area. Similarly, at times the worker may look toward a secondary task area to pick up a tool or check a drawing; or he may look up momentarily to rest his eyes from the stress of near vision. In all of these instances it should be obvious that visual consideration must be given to portions of the visual field other than the restricted task area. Every region that can be seen must be given its proper emphasis to satisfy the overall requirements of seeing.

From the foregoing brief discussion it is obvious that the key brightness is that of the visual task. All other brightnesses in the visual field should be related to it and must be in proper balance with each other. Glare is obviously an uncomfortable and undesirable condition. However, other brightness relationships, none of which produce a sensation of glare, may be equally undesirable and uncomfortable, especially to the worker who is exposed to them for prolonged periods.

Immediate Surround

Researches show that surroundings which are brighter or darker than central task areas decrease the visibility of objects in the latter. For example, in Figure 2 are illustrated the effects of the brightness of surroundings of the task upon contrast sensitivity.[2] It is seen that the sensitivity of the visual sense is greatest when the brightnesses of the surroundings and the task are the same. Furthermore, when the surroundings are brighter than the task, the reduction in visibility is greater than for darker surroundings. In other words, it is better to have the surroundings darker rather than brighter than the task. Similar results have been obtained when evaluations were made in terms of visual acuity[3] and accuracy of seeing.[4]

The data of Figure 2 also reveal that the rate of blinking while reading is increased by bright and dark surroundings.[5] In view of the fact that the rate of involuntary blinking invariably increases when the seeing conditions are made less

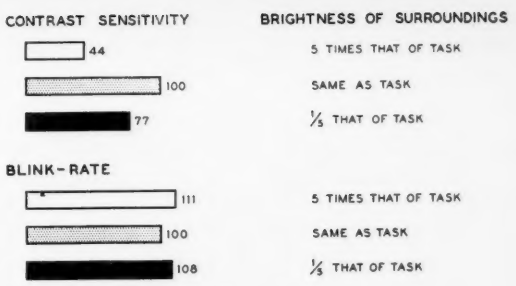

Figure 2.
The influence of the brightness of surroundings as compared with the brightness of the task as indicated by changes in contrast sensitivity and the rate of blinking.

favorable,[6] it follows that either brighter or darker surroundings are unfavorable.

The differential effects of brighter and darker surroundings for equal brightness ratios appear to be caused by the actual brightness differences between the two areas.[7] For example, when the task brightness is 25 foot-lamberts, a brightness ratio of five would result in brightnesses of five and 125 foot-lamberts for darker and brighter surroundings, respectively. The corresponding brightness differences are 20 and 100 foot-lamberts. In other words, for a given brightness ratio, the brightness difference for bright surroundings is many times that for darker surroundings. It seems obvious that the larger brightness difference should be expected to produce greater effects on visibility and ease of seeing.

Various investigations have shown that these brightness relationships between the task and its surroundings are of greatest importance within a 30° zone around the line of sight.[4] This does not mean that regions located more than 15° from the line of sight are unimportant. Extensive investigations show that large areas of even apparently moderate brightness are disturbing and produce discomfort and are distracting even when located at considerable angular distances from the normal line of sight.[8] High brightnesses or very dark areas should be avoided in any part of the visual field.

As has been stated, seeing is a dynamic activity of human beings. Since a worker may look at any part of a visual environment, it is important to eliminate extremes of brightness or darkness. If they are not eliminated, the worker's eyes must continually adapt to a greatly changing brightness pattern, with a resulting decrease in ease of seeing and corresponding reductions in visual performance as indicated by size or brightness discrimination and by rate of working. For example, the data of Table I illustrate the effects upon rate of blinking for three conditions of reading:[5] 1. with the book illuminated to 20 foot-candles; 2. during alternating periods of 15

seconds each with two and 20 foot-candles, respectively; and 3. with an illumination of two foot-candles on the book. The conditions in the second of the series of three tests are approximately equivalent to looking back and forth between two areas illuminated to 20 and two foot-candles. Since the duration of the reading period for each lighting condition was five minutes, the results are considered to be conservative. Higher relative rates of blinking for the less desirable conditions would be expected with prolonged periods of reading.

TABLE I.
THE EFFECT OF READING UNDER THREE LIGHTING CONDITIONS UPON RELATIVE RATE OF BLINKING

Lighting Condition	Relative Rate of Blinking
Uniform 20 ft-c	100
Alternating 2 and 20 ft-c	122
Uniform 2 ft-c	111

Unfortunately, most rate of working experiments involve a certain amount of response limitation, i.e., doing something after receiving a stimulus before being able to respond to the next stimulus. Thus, rate of working usually is a relatively insensitive criterion. Nevertheless, in an experiment[9] which involved rapidly seeing details alternately on light and dark surfaces, using 100 foot-candles as a base, a five to one brightness ratio between central and surrounding areas produced the same decrement in rate of working as about a 30 to one reduction in illumination. Other more sensitive criteria and techniques which are not response limited would be expected to show even more marked differences.

These results emphasize the importance of proper brightness relationships between a task and its immediate surround and also between two work areas which must be viewed alternately in order to perform a given task.

More Remote Regions

In typical visual situations the brightnesses of luminaires often are a source of discomfort. While they may be located anywhere from a few degrees up to 60° from a horizontal line of sight, luminaires occupy a relatively large portion of the upper visual field. Thus, what may be considered relatively moderate brightnesses often produce considerable discomfort and distraction. Therefore, in a well integrated environment it is important to control the brightness of lighting equipment.

Certain basic factors which influence visual discomfort have been studied by many investigators:[10] 1. The brightness of the source or luminous area. 2. The visual size of the source. 3. The position of the source with respect to the line of sight. 4. The brightness level to which the eyes are adapted. Several other factors, such as the number of sources in the visual field and the criticalness of the visual task being performed have important modifying influences upon the basic factors. The factors have been divided in this manner because it has been found that the basic ones can be incorporated in a formula, whereas the modifying factors govern how the formula is used. For practical purposes, evaluations of direct discomfort glare usually are made for the condition of so-called casual seeing. That is, the visual situation is rated when an observer looks up from his work to a generally horizontal line of sight. This does not mean that discomfort glare cannot be a problem when one is looking down toward a task. However, in this latter viewing condition the line of sight usually is 30° to 45° or more below the horizontal and most luminaires are not seen. Nevertheless, discomfort glare evaluations can be made by using any desired line of sight as a reference.

Since comfort and discomfort are sensations it is necessary to use subjective techniques for evaluating discomfort glare. In order to simplify the procedure the sensation criterion of the borderline between comfort and discomfort was selected.[8] This is termed the BCD sensation and the brightness producing this sensation is the BCD brightness.

The relationships between the BCD brightness B of a source located on the line of sight and the size of source Q, for three values of field brightness F are illustrated in Figure 3. The inverse relationship between BCD brightness and size of source is obvious and agrees with experience. However, it is a variable relationship, and a change in one factor required as a result of an increase or decrease in the other factor is dependent upon the absolute values of size and brightness which are involved. For example, when the size of the source is increased 10 times from 0.001 to 0.01 steradian,* its brightness must be reduced by a factor of about two. On the other hand, when the area is increased from 0.01 to 0.1 steradian, its brightness must be further reduced by a factor of four. Similarly, for a given BCD brightness, when the size of the source is small, doubling the field brightness permits increasing the source size about 2.6 times. However, when the size of the source is large, its area may be increased by a factor of only 1.3 when the field brightness is doubled.

While the sources in a lighting installation often may be viewed directly, in the usual situation they are located an appreciable angular distance from the normal line of sight. The effects

* A steradian is the measure of the solid angle subtended by a source and is equal to its projected area divided by the square of its distance from the eye. At a distance of 20 feet, 0.1 steradian corresponds to a projected area of 40 square feet; the actual area of luminaires will be considerably greater.

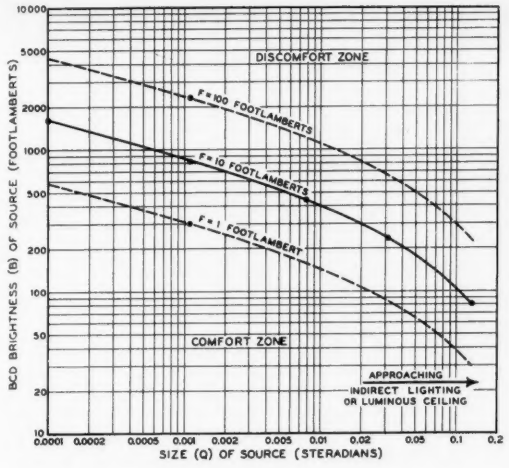

Figure 3.
The relationships between the brightness B producing a sensation at the borderline between comfort and discomfort (BCD) and size Q of sources located on the line of vision for three field brightnesses F.

of such displacements are illustrated in Figure 4. From these curves it is seen that a source of given brightness produces a greater visual sensation when displaced horizontally from the line of sight than when it is displaced the same angular distance vertically. For example, a source having a brightness of 2,000 foot-lamberts must be displaced 50° horizontally but only 23° vertically to be at the borderline between comfort and discomfort. Or, stated in another way, a 2,000-foot-lambert source displaced 50° horizontally and a 7,600-foot-lambert source displaced the same angular distance vertically are both BCD brightnesses for the standard viewing conditions.

In Figure 5 are illustrated diagrammatically how changes in one factor must be compensated for by changes in the other factors to maintain the BCD sensation. For a constant field brightness, moving a source farther from the line of sight permits increasing its size or brightness, as indicated by the diagonally displaced circles. Similarly, when the position factor is constant, the horizontally displaced circles illustrate how the brightness must be reduced as the area is increased.

Using the basic relationships illustrated in Figures 3 and 4, it is possible to derive a formula for computing a discomfort rating produced by sources of brightness:

$$M = \frac{B}{P\ F^{0.44}\ (Q^{-0.21} - 1.28)}$$

In this formula, M is an index of the sensation of visual discomfort produced by a combination

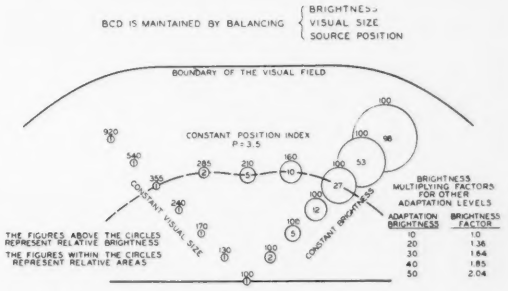

Figure 5.
A diagrammatic representation of the relationships among the basic factors to maintain a visual sensation at the borderline between comfort and discomfort.

of source brightness B, size Q, position index P, and field brightness F. When the values of these factors are such that M is equal to 108, the sensation is at the borderline between comfort and discomfort, or BCD for the average observer.

One point illustrated by experiments of this type is the difference among various observers.[11] Individuals vary considerably in their evaluation of what is comfortable or uncomfortable. For example, with a group of 50 observers and standardized viewing conditions, there was a range of five to one in the brightness judged to be at BCD. That is, the average of all observers was 830 foot-lamberts, but the most sensitive and least sensitive observers selected 315 and 1,600 foot-lamberts, respectively, for the BCD sensation. A probability plot in terms of the percent of a given group who would be expected to judge a specific combination of source size, position and brightness and the field brightness to be at or more comfortable than the borderline between comfort and discomfort is shown in Figure 6. For example, if the formula indicates M to be 160 for a specific combination of the factors, only about 10% of a group could be expected to be comfortable. On the other hand, if M is about 50, 95% would be expected to be comfortable.

More recent data being obtained with a large group of observers and actual lighting installa-

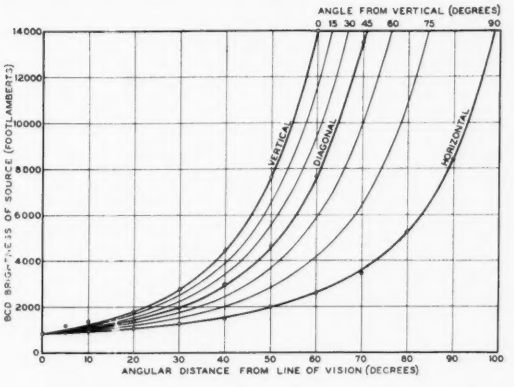

Figure 4.
The effect upon the BCD brightness as a source is displaced along various meridians from the line of sight.

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tions are confirming these basic relationships.

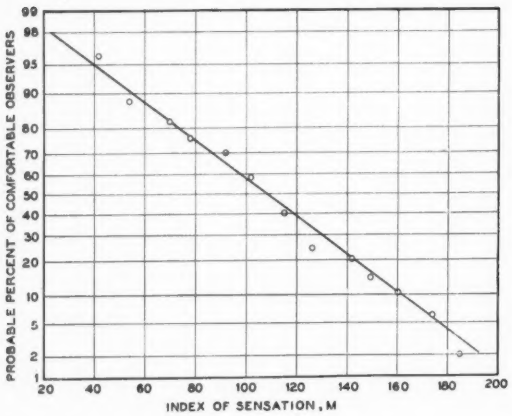

Figure 6.
The relationship between the probable percent of observers who would be expected to find that the index of sensation M representing a given combination of brightness conditions to be at or more comfortable than the borderline between comfort and discomfort.

Applying The Basic Data

It should be obvious that while there is considerable information available on quality of lighting, much more is needed before there is sufficiently complete knowledge to cover every situation which may be encountered. Nevertheless, the available data permits development not only of certain generalizations, but also of some specific methods for evaluating quality of lighting. Over the past decades much has been gained from carefully devised investigations and this new knowledge has been applied with considerable success.

It is necessary to remember that one is dealing with the entire visual environment and that all pertinent factors must be considered in order to make the environment visually desirable. As has been indicated in this brief discussion, achieving quality of lighting involves a consideration of at least two important items: 1. the brightness relationships between the task and its immediate surround and 2. the brightnesses of luminaires and lighting equipment.

As a general guide, a characteristic of high quality lighting is that objects and areas which should not be seen are as inconspicuous as possible. At least their visibilities should be such that they do not compete significantly with that of the task or work being performed.

A simple rule which is consistent with the experimental evidence and with experience is that when the brightness ratio between the surround and the visual task is not greater than three, very good seeing conditions should result. With general lighting, this means that the reflectances of surrounding areas should not be less than about one-third that of the task. When supplementary lighting is used on darker tasks the reflectances of surroundings must be adjusted so that the brightness ratios are not excessive. It should be obvious that brighter surroundings are undesirable. One reason for having the task somewhat brighter than the surroundings would be to help attract and hold the attention of the worker.

It must be emphasized that brightness ratios are not necessarily constant. The brightness difference between a task and its surround, even for a ratio of three may become numerically large at higher foot-candle and brightness levels. Its magnitude may be such that, even though it conforms to an apparently desirable ratio, discomfort is produced. This is confirmed by a consideration of the BCD data for large sources and a 90% comfort rating.[7] This emphasizes the care with which quality of lighting must be designed. Nevertheless, brightness ratios are workable and simple guides for achieving the desired end results.

The matter of discomfort glare from lighting equipment is not as simply handled. It involves a complex relationship among a number of factors. However, visual comfort index tables[12] have been devised which rate typical luminaires in various sizes of rooms. Such tables have been found very helpful in selecting luminaires for those areas where visual comfort is necessary and desirable. As the results of further researches now under way in several laboratories become available, such tables will be modified as indicated by the new knowledge.

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Light AND ITS MEASUREMENT

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It should be realized that the subject of light and its measurement is a very complex one that cannot possibly be covered in a short paper. I will be unable to elaborate such important aspects as photometric standards, measurement techniques, conversion of photometric units, or colorimetry. Those who wish more detailed treatments will find many good textbooks on these subjects such as *Introduction to Geometrical and Physical Optics* by Morgan, *Optics* by Sears, *The Science of Color* by the Committee on Colorimetrics of the Optical Society of America, and many others.

First, let us ask a question that has interested scientists and philosophers for centuries. What is light? According to modern quantum theory it is composed of bundles of energy called photons which are emitted from hot objects and other light sources somewhat like bullets from a machine gun. Apparently contradictory is the electromagnetic theory, according to which light somewhat resembles the waves which can be made to follow along a long, tightly stretched rope. It is puzzling that the results of some types of experiments with light seem to be explainable only on the basis of one theory, while others point directly to the other theory. Actually both are now accepted as correct, and the principal reason for the apparent contradiction is that we are tempted to extend the corresponding analogies too far. Light is not like bullets, or like waves along a rope, or like anything else except in a very limited sense. Sometimes one analogy is useful to help us partially understand what we observe and sometimes another is, but none should be expected to apply under all circumstances.

For our present purpose, the electromagnetic theory is useful. According to this theory, a light ray is composed of waves of magnetic and electric fields. As time progresses, the entire wave moves forward so that the field strength at a stationary point oscillates between a positive and a negative value just as a single point on the rope moves up and down. A plane-polarized light ray is one in which the electric fields are all in one plane and the magnetic fields in another, while an unpolarized ray is composed of many such components of random orientation.

The wavelength of the light is the distance from one crest to the next, and the frequency is the rate of oscillation of the fields at a stationary point in space. Since for various wavelengths of radiation the velocity in vacuum is the same (186,000 miles per second), wavelengths and frequencies are inversely related. In the radio region of the electromagnetic spectrum it is customary to specify frequencies, while in other regions, wavelengths are more commonly used.

The human eye is insensitive to electromagnetic radiation except in a very narrow range from about 400 to 700 millimicron wavelength. This is the interval which is usually referred to as "light," as opposed to other, nonvisible forms of radiation. The standard curve of eye sensitivity, called the standard luminosity function, reaches its maximum value of unity at 555 millimicrons and tapers off on both sides to nearly zero at 400 and at 700 millimicrons.

Before we attempt to measure light, we must be sure we know the exact meaning of the quantities we will be dealing with. Most of the electrical power, measured in watts, that goes into a lamp is converted into radiant flux, also measured in watts. The total radiant flux from a lamp radiates in straight lines and covers a broad spectral range. We can also, if we choose, specify the flux contained within a smaller solid angle, or within a narrower spectral range, or the flux incident upon a surface. We cannot, however, deal with the flux incident upon a single point on a surface because a point is infinitely small and would therefore receive an infinitely small amount of flux. Instead, we define the irradiance at a point to be the amount of flux incident on a small area surrounding the point, divided by the area itself. Thus as the area is made smaller, the flux also becomes smaller and the ratio approaches a constant.

Also, we cannot deal with the flux in a single direction from a source because that contained within an infinitely small solid angle is also zero.

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Instead, we define the radiant intensity in a particular direction as the flux in a small solid angle divided by the size of the solid angle.

Similarly, we cannot deal with the flux at a single wavelength because the amount of flux contained within an infinitely narrow wavelength interval is zero. Instead, we define spectral radiant flux to be the flux in a narrow wavelength interval, divided by the width of the interval. The symbol for spectral radiant flux is $P\lambda$ and its unit is the watt-per-millimicron.

The most basic photometric quality is luminous flux, which is like radiant flux except that the amount of power at each wavelength is weighted according to the standard luminosity function. Thus a warm object such as a teakettle on the stove produces radiant flux but no luminous flux. The symbol for luminous flux is F, and its unit is the lumen. At the peak of the luminosity function, one watt of radiant flux is equivalent to 680 lumens, while for other wavelengths the number of lumens per watt is less. The equation relating these quantities is:

$$F = 680 \int P\lambda \, v \, d\lambda$$

in which v is the value of the luminosity function at each wavelength and λ is the wavelength.

The next photometric quantity we shall consider is luminous intensity, sometimes called candlepower. This is, roughly speaking, the angular concentration of luminous flux from a small source of light. We might expect the unit to be the lumen per steradian, but instead it is called the candle, for historic reasons.

When the intensity of a source is constant within, let's say, a 10° cone, we can find the intensity by dividing the flux, F, contained within that cone by the size of the cone, ω, in this case .024 radians.

$$I = \frac{F}{\omega}$$

On the other hand, if the intensity is different in each direction, the intensity is found by dividing the flux $\triangle F$ (in lumens) contained within a very small cone by the size of the cone $\triangle\omega$ (in radians).

$$I = \frac{\triangle F}{\triangle \omega}$$

If the cone is small enough, making it smaller reduces the flux proportionately, and the ratio remains unchanged. Thus radiant intensity and luminous intensity are alike except that the latter is weighted by the luminosity function.

The next quantity is illuminance. Most people speak of the "illumination on a surface," but recent textbooks use the term "illuminance" when referring to a quantity of illumination. In the English system the unit has two names, the foot-candle and the lumen-per-square-foot.

If the illuminance of a surface is constant over an area of, let's say, one-tenth of one square foot, the illuminance is equal to the flux incident on that area divided by one-tenth.

$$E = \frac{F}{A}$$

If the illuminance is variable over the surface, the flux $\triangle F$ (in lumens) incident on a very small area, divided by the area $\triangle A$ (in square feet) is the illuminance at that point.

$$E = \frac{\triangle F}{\triangle A}$$

The area must be chosen small enough that making it smaller would reduce the flux proportionately. Thus illuminance and irradiance are comparable photometric and radiometric quantities.

The most difficult term of all is luminance. Most people continue to speak of the brightness of a surface, but brightness is now defined in most texts to be a visual sensation, whereas luminance is a physically measurable quantity.

One of the reasons for the difficulty in defining this quantity is that in both the English and the metric systems, it has two units which differ from each other by the constant factor π. In the English system they are the foot-lambert and the candle-per-square-foot. To make matters worse, the same symbol B is often used with both luminance units, so that it is impossible to tell from an equation which one is meant. In other fields an equation is correct in any consistent set of units, but in equations involving luminance, the units must always be specified.

For luminance in units of lumens per square foot, the defining equation is:

$$B = \frac{\triangle I}{\triangle A \cos \theta}$$

This says that if the luminance of a surface in a specified direction is constant over the area $\triangle A$ on that surface, it is equal to the intensity $\triangle I$ of that area in a specified direction, divided by $\triangle A \cos \theta$, in which θ is the angle between the normal to the surface and the specified direction. When the luminance is not constant over the surface, a small enough area must be chosen surrounding each point that making it smaller would reduce $\triangle I$ proportionately.

The corresponding definition of luminance in foot-lamberts is:

$$B = \frac{\pi \triangle I}{\triangle A \cos \theta}$$

The reflectance of a surface is another quantity which is not as simple as it first appears. First, it is in general a function of wavelength, so that the spectral distribution of the light source and the spectral sensitivity of the receiver are important. Strictly speaking, every measurement of reflectance should be made with monochromatic

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light if it is to have any generality, but useful engineering approximations are often made using "white light." Secondly, the polarization of the light source and of the receiver is another important factor for all materials, particularly at some angles, but this effect usually is ignored. Large errors are sometimes introduced thereby, because in practice most light is at least partially polarized; but here again, engineering approximations must be made to achieve simplicity. And thirdly, the spatial distribution of the incident light and of the type of light-collecting system are extremely important. This is such a large effect that it cannot be ignored in practice. For mirrors, the specular reflectance is the ratio of the luminance of an image to the luminance of the object. Usually the term "reflectance" refers to the luminance, in foot-lamberts, of the reflecting surface in a given direction to the illuminance, in lumens-per-square-foot, also in a given direction.

$$R = \frac{B}{E}$$

A perfectly diffusing reflector or lambert surface has equal luminance in all directions regardless of the direction of the incident light, so that its reflectance is independent of the method of measuring it. For this special type of surface the maximum possible value of reflectance as defined above is unity, while for many real materials the reflectances exceed unity at some angles.

Transmittance, like reflectance, is a function of wavelength, polarization and spatial considerations. For lenses and filters, the specular transmittance is a luminance ratio. For diffusing materials, the transmittance usually refers to the luminance in foot-lamberts divided by the illuminance in lumens-per-square-foot on the reverse side.

$$T = \frac{B}{E}$$

The only other photometric relationship which we need for most work is the inverse square law:

$$E = \frac{I \cos \phi}{D^2}$$

in which D is the distance from the source to the illuminated surface, and ϕ is the angle between the normal to the illuminated surface and the line from the source to the illuminated point.

Below, I briefly have described a few photometers for measuring luminance and illuminance (or "brightness" and "illumination").

There are three types of visual photometers in common use, the Macbeth Illuminometer, manufactured by Leeds and Northrup Co., the Luckiesh-Taylor Brightness Meter by the General Electric Co., and the SEI photographic exposure meter (with a log foot-lambert scale) made in England and sold in this country by the Zoomar Corporation. Each of these contains a lamp which illuminates a diffusing surface. The luminance of this surface is manually adjusted until it visually matches the unknown luminance. The number of foot-lamberts is then read from a scale.

For measurement of illuminance above a few foot-candles there are many varieties of barrier layer cell such as the G. E. Foot-candle Meter and the Weston "paddle meter."

The Spectra Brightness Spot Meter made by Photo Research Corporation has a field of view of about 1° and employs a vacuum phototube as the sensing element. The luminance of the unknown is read directly on a meter.

For measurements of small quantities of light a photomultiplier photometer made by the American Instrument Co. is an extremely sensitive device. To correct the spectral sensitivity of the photomultiplier to approximately that of the eye, a Wratten No. 106 color filter may be used.

Each of these devices is different in regard to accuracy, convenience, portability, sensitivity, field of view, cost, reliability, etc. It is difficult to rate any one as "the best."

Industrial Medicine & Surgery must have several copies of the April, 1958, issue to complete its committments to medical libraries and research centers for bound copies. We must turn to our readers to help us collect the missing copies. If you no longer need your *Industrial Medicine & Surgery* journal for April, 1958, please mail it to Industrial Medicine & Surgery, P. O. Box 44-306, Miami 44, Florida. Mail it at the "printed matter rate" and we pay the postage, of course.

XUM

Application of

The Four Factors of Seeing

To a Variety of Industrial Situations

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The amount of light required to perform a specific seeing task with reasonable efficiency is in many instances well established through research and practice. The amount of light required for other seeing tasks is then related to these findings and we have a listing of the relative foot-candles required as follows:

Multiplying Factors to Obtain Foot-candles for Equal Visibility[1]

Typing, used black ribbon, elite type	1
Stencil duplication, elite type	2
Magazine text	2
Handwriting in pencil	4
Newspaper text	4
Shorthand notes, pencil	5
Drafting, pencil	8
Telephone directory	10
Handwriting on chalkboard	13
Medium grade assembly and inspection	15
Metal buffing	17
White thread on white cloth	21
Metal finishing	36
Newspaper stock quotations (fractions)	42
Black thread on black cloth	90

To have a better understanding of the logic behind these recommendations it is necessary to review some of the basic elements of seeing as related to the visual task. They are referred to as the Four Factors of Seeing.

1. *Size of the Object:* Reading the headline of a newspaper is a simple task even in very dim light. However, studying the classified-ad section is quite a different story, and the size of type makes that difference. Comparable seeing tasks in industry might be that of reading the micrometer calipers as compared with sorting large castings. These are extremes, of course, but many manufacturing, assembly and inspection jobs have this element of size which must be reckoned with by providing a large amount of light and sometimes magnification when the detail is minute. The low visibility of small objects can, within limits, be compensated for by supplying higher intensities of light.

2. *Reflectance of the Object:* In general, it is easier to see those objects which reflect the most light. The white golf ball and baseball, both being of high reflectance, are good examples of this, and if pedestrians wore white capes when crossing the streets at night, the lowered mortality statistics would furnish confirming testimony. An example in industry might be the task of inspecting case-hardened steel screws which are dark as compared to inspecting aluminum screws. Here again, more light on the dark object provides a compensating factor in visibility making it easier to see.

3. *Contrast of the Object With Its Background:* When plating nickel on copper the areas of copper not covered by the nickel are easy to see because of high contrast. Incomplete coverage of chrome on nickel, however, is difficult to detect because of very low contrast. To be easily seen, the details of the object must differ in reflectance or color from the surrounding background. This can be accomplished in some cases by putting more light on the work. In some situations special lighting techniques are employed such as ultraviolet radiation and fluorescent dye, directional lighting, etc.

4. *Time Available to See the Object:* This element of seeing is involved in many inspection operations where minute flaws must be detected at a glance and the defective part rejected. It is also involved in the quick action sometimes necessary to avoid an accident. It takes time to see and, within limits, the time required to see can be reduced by simply providing more light.

One of more of these four factors is involved in every task the eye is required to perform,

1. Foot-candles in Modern Lighting Practice *General Electric Bulletin*, LS-119, March, 1957.

and where that task cannot be changed, usually an adjustment in the quantity and/or quality of illumination will provide an improvement.

These improvements in visibility may benefit both the employer and the employee. They will occur in one or more of the following categories:

1. Greater ease of seeing is particularly important to the older workers whose skill and knowledge in the performance of their daily work are limited by failing eyesight.

The younger workers also benefit by experiencing less eye strain and fatigue. A large percentage of young workers have eye defects which good lighting can help to overcome.

2. Increased Production. The more light on the work, the greater the speed and accuracy of seeing. The extra seconds needed to make sure of a fine detail are eliminated in a properly lighted situation, and in a repetitive process this becomes a substantial item contributing to the production rate.

3. Better Workmanship. Some defects can be seen under good light before the part has gone through all of the manufacture or assembly operations. Hence, there is less waste of time, labor and materials by spotting the defect early.

4. Better housekeeping is likely to result from good lighting practice because it provides a powerful incentive to keep the plant free of the accumulation of rubbish and waste. In a poorly lighted plant the tendency is to let the debris accumulate because it is difficult to see under benches and machines and in dark corners.

5. Better supervision of workers will result when the supervisor can explain the work and show the worker his mistakes at the work location rather than in the "highly refined lighting" of the inspection room.

6. Safety involves many factors but some accidents can be avoided if the lighting is adequate to provide split-second seeing.

7. Employee morale involves many factors, but a well-lighted and properly decorated plant has a stimulating effect upon employees. Other things being equal, employees prefer the well-lighted plant to one that has a gloomy appearance.

In many cases it is difficult to evaluate, in terms of dollars saved, the benefits derived from good lighting. However, the constant improvement in quantity and quality of plant lighting is ample evidence that this is a key factor in raising industrial productivity.

Labeling Hazardous Substances in Packaged Chemicals

The growing demand for uniform legislation to require precautionary labeling of all chemical products, which are not now so regulated, was discussed at the first legislative conference held on May 9, 1958, at the American Medical Association Headquarters. Speaking to government, industry, and medical representatives from approximately 40 national organizations, members of the AMA Committee on Toxicology discussed the "Uniform Hazardous Substances Act" and compared it with other tentative legislation which has been proposed. Attention was focused on the general nature of the problem, as seen by the medical profession, public health officials, and the public, by remarks from a pediatrics representative, and officials of the American Public Health Association and the National Safety Council. The principles, which the Committee employed in formulating the provisions of a model law for labeling all types of hazardous substances, were next reviewed. A comparison of the model bill with other tentative legislative proposals followed. An industry-wide label law conference was held on July 25, 1958, under the sponsorship of the Committee on Toxicology. The second meeting discussed proposed legislation requiring the declaration of hazardous ingredients and warning statements on the label and in the accompanying literature of household, commercial and industrial packaged chemicals. Over 100 organizations including representatives of trade associations, toxicity testing laboratories, chemical trade unions, and other interested groups were invited to participate. This was the second of several meetings which will be held to discuss proposals for local and federal regulations to close the gap in label legislation. A Committee survey showed a sketchy, nonuniform, and generally inadequate pattern of labeling regulations at the state and national level. Ninety percent of the states lacked requirements for precautionary labeling of commercial as well as household chemical products. These meetings were held to bring about a clearer understanding of what the model bill is intended to cover and the benefits to be derived from such legislation.

—From *A.M.A. Archives of Industrial Health*, September 1958, Volume 18, Number 3, Page 273.

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Summary Description of

A Generalized Method for Specification of Interior Illumination Levels

On the Basis of Performance Data

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This paper presents a summary description of a generalized method for specifying the interior illumination requirements of practical visual tasks on the basis of visual performance criteria. This method has recently been applied to specifying illumination requirements for a number of practical visual tasks provided by various technical committees of the Illuminating Engineering Society. A more complete description of the method may be found in a forthcoming issue of *Illuminating Engineering*.

There are basically two components of the method; visual performance graphs for standard circular targets, and a device for equating various practical visual tasks to standard circular targets. The method is based upon the philosophy that it is not practical to expect to obtain performance data for all practical visual tasks, suitable for use in specifying illumination levels for the tasks. Instead, we obtain extensive performance data for one visual task and then determine equivalences between other tasks and the standard task. This approach involves the assumption that tasks equal to one another when evaluated under one condition would yield equivalent performance data over the entire range of conditions of interest. Within the limits of currently existing data, this assumption appears reasonable.

Visual Performance Data for Standard Circular Targets

Performance data have been obtained on circular targets of uniform luminance (brightness), presented on fields of otherwise uniform luminance. Extensive data have been obtained under conditions in which the eye was static, with controlled amounts of information presented for controlled periods of time. A limited number of comparative data have been obtained under dynamic conditions of search and tracking of the eyes, in which the informational input was again controlled so that we could properly assess it.

We began by evaluating the minimum number of items of information the eye normally assimilates per second, during normal dynamic use of the eyes. Data of Ginsburg[1] suggest that the normal eye makes about four fixational pauses per second, each of 0.200 second duration. Experiments by my colleague W. C. Clark[2] reveal that the static eye can assimilate at least two items of information at a given point in space in a fixational pause of this length. Experiments by my colleague E. R. Harcum[3] reveal that the static eye can assimilate at least eight items of binary information from various points in space in a fixational pause of this length. (By binary information, we mean information which can have one of two possible forms).

We do not know precisely how many items of information can be assimilated per fixational pause when information is more complex. It seems virtually certain however, that the eye is capable of assimilating more than one item of information per fixational pause. Thus, we might set limits on the assimilation capacity of the normal eye between four and 32 per second, based upon between one and eight assimilations per fixational pause. The illumination specification system to be described here is based upon providing enough light so that the eye will be able to perform at the level of five assimilations per second (APS), which is certainly a very conservative estimate of the normal assimilation capacity of which the eye is capable.

Experiments have been conducted to discover the illumination required to assimilate the information contained in simple circular targets of uniform luminance at the rate of five APS.

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To insure that we can specify the assimilation rate, we used the static eye and presented targets for only one-fifth second duration. For each target presentation the observer had only to detect the presence of the target, not identify any qualitative aspects of it. Since the target was either presented or not presented, there was only one item of information presented in each one-fifth second duration. Hence, we consider the information to have been presented at a five APS rate.

The observers were seated in special light cubes as shown in Figure 1. The walls of the cube were uniformly and diffusely lighted. The target was presented from time to time by projecting a spot onto the rear of a translucent screen which made up the centermost portion of the wall opposite the observers. The spot could be varied in size from day to day. Within an experimental session, the luminance of the spot was varied so that it

Figure 1.
The observers in the cube. The circular standard targets are presented through the translucent screen facing the observers by transillumination.

was barely visible on some presentations and invisible on others.

The observers were required to demonstrate that they were able to detect the presence of the spot by correctly identifying in which one of four possible time intervals it appeared on each presentation. The observers were forced to guess when they were not certain. After considerable practice, observers learn to identify the correct time interval most of the time for spots which they were originally unable to "see." The extreme sensitivity of the observers is in part due to their learning to detect very faint spots of light with which they have previously had next to no experience, and in part due to that fact that they have a very unusual amount of information about the spot which is to be presented. They are aware when and where the spot will be presented, and they are familiar with its size and shape. The observers also are given sufficient warning before the spot is presented so that they can align their eyes precisely and can perfect their ocular accommodative and vergence adjustments.

It is possible to score the accuracy with which the observers can correctly identify the time interval occupied by the target. After allowing for successes due to chance guesses, the data have the form shown in Figure 2. Here the percentage accuracy is plotted against the contrast, or percentage luminance difference between the spot and its immediate surrounding. There are five data points at different values of contrast, provided by different spot luminances. The smooth curve is a frequency-of-seeing curve which is fitted to the data points by a computation technique developed by my associate, W. M. Kincaid,[4] which employs an IBM 650 computer.

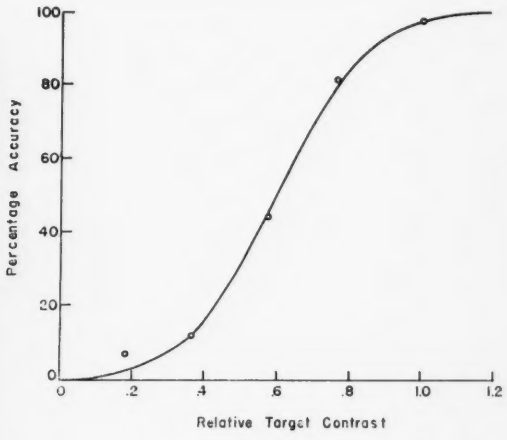

Figure 2.
Typical accuracy data for various values of target contrast. The open circles are the experimental points and the solid curve is a normal ogive fitted to them by probit analysis.

The performance index known as the threshold is defined in this case as the contrast required to produce 50% accuracy. Under the conditions of these experiments, threshold targets are virtually never seen with any appreciable confidence even by thoroughly practiced observers. This index is used because it may be defined with great accuracy, and because it is a stable measure which does not vary appreciably from day to day.[5]

Figure 3 presents threshold data for spots of different sizes. Each curve exhibits the contrast of a particular spot needed to detect it for various values of the luminance of its surrounds. In all cases, the one item of information was presented for only one-fifth second so that the static eye was being required to perform at the five APS level. The data in Figure 3 provide the

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fundamental basis for the specification of illumination by the present method.

The problem in utilizing the data from Figure 3 directly for specifying illumination levels is that no one wants to light in order to provide only the capacity for the most highly trained observers barely to see under the most favorable conditions imaginable. We require, therefore, some criteria upon which to base lighting to provide a more reasonable level of visual performance.

We may begin by specifying that lighting must provide more than 50% accuracy. The curve in Figure 2 suggests that we can obtain any desired level of accuracy by increasing the target contrast. It has been shown elsewhere[6] that a constant multiplicative factor in contrast allows for the change from one accuracy level to another, for different levels of background luminance and for different target sizes. For one-fifth second duration, a constant multiplier of 1.99 is required to increase the accuracy level from 50% to 99%. An accuracy level of 99% is considered the maximum practical level of accuracy, since one error in 100 target presentations may reasonably be expected to result from a lid blink or other artifact.

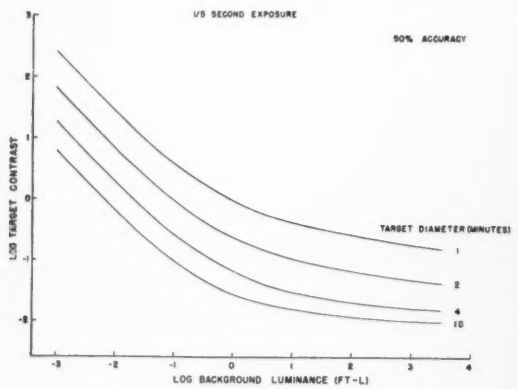

Figure 3.
Basic laboratory performance data for 50% accuracy. Each curve represents the relation between target contrast and surround luminance for a target of the size indicated.

We need next consider the extent to which the observers in our laboratory experiment can see better than similar observers who are required to use their eyes in a more normal fashion. As noted above, the laboratory observers have sufficient time to adjust ocular accommodation and vergence and to correctly align their eyes. They also have complete knowledge concerning the target. In most practical situations, observers have only incomplete information about the visual task, and they are required to scan and track with their eyes in a complex manner.

In order to assess the influence of all these differences between our original laboratory set-up and practical conditions for using the eyes, we have constructed a Field Task Simulator, shown in Figure 4. The Simulator consists of a circular plywood wheel of eight foot diameter, which can be rotated at any desired speed. A total of 50 four inch diameter white discs were positioned around the circumference of the wheel. When the wheel was rotated, the discs moved past the observer simulating the linear progression of items placed on a continuous belt. Each disc had a white surface consisting of translucent plastic. A small target spot could be added to the center of the disc by transillumination of the plastic from a projector mounted beneath. The observers were required to examine each disc, looking for "imperfections" in the form of the small spots of light. When an imperfection was located, the observer marked it by depressing the gray button mounted adjacent to the disc. The observing booth was of such a size that six discs were always visible at one time and the observers could depress any of the six corresponding buttons. This meant that the observer could perform an efficient inspection by examining a given disc, then depressing the button if an imperfection were found while examining other discs. The wheel was always turned through one complete rotation and then stopped. On the average, three spots were present among the 50 discs; the number present on a given rotation of the wheel was varied from one to six so that the observers would not know what to expect.

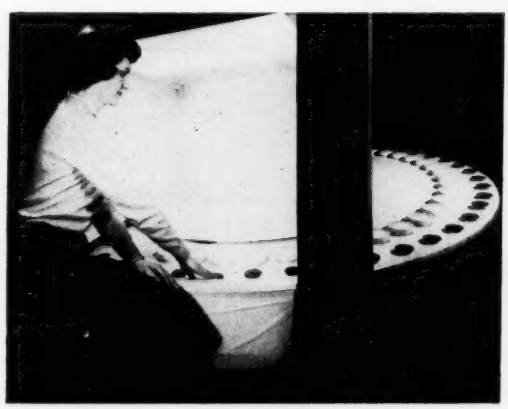

Figure 4.
An observer in the Field Task Simulator. The white discs are visible, as are the gray indicator buttons.

Two sets of experiments have been completed with the Simulator, for one size circular target. The results from the first experiment are presented in Figure 5. The filled circles are the raw experimental data. The data represent values of spot contrast needed to provide 50% accuracy in

identifying the imperfections, for each of a number of levels of general luminance within the observing booth. The wheel was rotated once in 50 seconds. Since there were 50 discs to be examined for imperfections, it was considered that the information the observer was required to assimilate could be specified as one item per second. (We refer to an informational input limitation of one item per second to emphasize the fact that the Simulator task has very little informational content in comparison with most visual tasks.) The solid curve in Figure 5 represents data from the original experiment when the single target was presented for one second. This condition is also considered to represent an assimilation rate of one item per second.

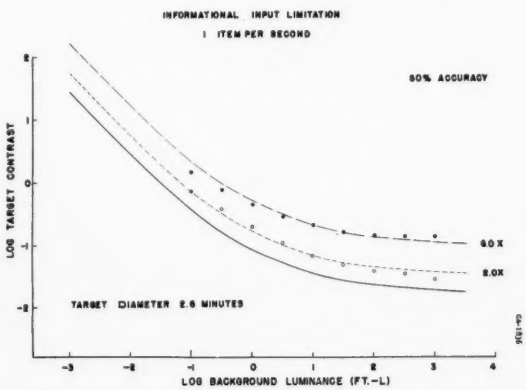

Figure 5.
Data from the Simulator, when the wheel rotated once in 50 seconds. The filled circles are the raw data, representing values of target contrast and surround luminance. The solid curve represents comparable basic laboratory performance data.

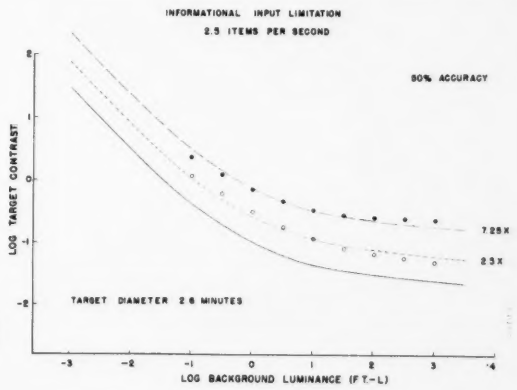

Figure 6.
Data from the Simulator, when the wheel rotated once in 20 seconds. The filled circles are the raw data, representing values of target contrast and surround luminance. The solid curve represents comparable basic laboratory data.

The raw data have been fitted by the upper dashed curve in Figure 5, which has been constructed by multiplying each contrast value on the solid curve by 6.0. Therefore, the upper dashed curve is parallel to the solid curve, displaced vertically by a distance equal to the logarithm of 6.0. The data appear to fit the curve reasonably well, so that we may conclude that multiplying the contrast obtained in laboratory experiments by 6.0 apparently allows for the influence of the various differences between the laboratory conditions and those built into the Simulator. (The open circle data and the lower dashed curve do not concern us here).

In the second experiment, the wheel was speeded up so that it rotated completely in 20 seconds. Thus, the observer was required to examine 50 items in 20 seconds. This requires a level of information assimilation of 2.5 items per second. The raw data from this study are exhibited as filled circles in Figure 6. The solid curve represents data from the original laboratory experiments in which a single spot was presented for a fixed time of 0.4 second. The upper dashed curve has been constructed to fit the raw data, by multiplying each value on the solid curve by 7.25. As before, this means that a factor of 7.25 apparently allows for the influence of the various differences between the laboratory conditions and those built into the Simulator. (In this case also, the open circle data and the lower curve do not concern us here).

Separate experiments which can only be mentioned briefly here suggest that between 2.0 and 2.5 of the factors required to account for the differences between laboratory conditions and those in the Simulator may be considered due to the reduction in knowledge about the target which characterizes the Simulator situation. The remainder of the factors, in the range from 2.9 to 3.0 can reasonably be accounted for by assuming that the observers in the Simulator were unable to align their eyes accurately with the rapidly moving discs during search and scanning for the small spot imperfections.

Regardless of interpretation, these two experiments do suggest that multiplying the required contrast by from 6.0 to 7.25 allows for the differences between laboratory conditions and the conditions of dynamic use of the eyes represented by the Simulator. Use of a correction factor of this magnitude is the first step, therefore, in applying our basic laboratory performance data to the problem of illumination specification.

It is to be emphasized that both the original experiments and the Simulator experiments were conducted with highly trained laboratory observers. Presumably, we wish to light so as to provide a reasonable level of performance for ordinary people, operating under what might be

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called "common sense conditions of seeing." We require, therefore, some measure of the extent of difference between ordinary seeing and visual discrimination carried out by highly trained observers utilizing the forced-choice technique. Figure 7 presents data for 77 observers which are appropriate for this purpose. When first brought into the laboratory, these observers were asked to state "yes" when they could and "no" when they could not see a standard circular target. Their average accuracy data are represented by the curve at the extreme right edge of the lined area. Subsequently, the observers were trained in the use of the forced-choice technique. After at least 10 hours of training, they were considered fully practiced. Their average results with forced-choice after practice are represented by the separate curve to the extreme left in Figure 7. These data exhibit the fact that the difference between the contrast needed for ordinary seeing

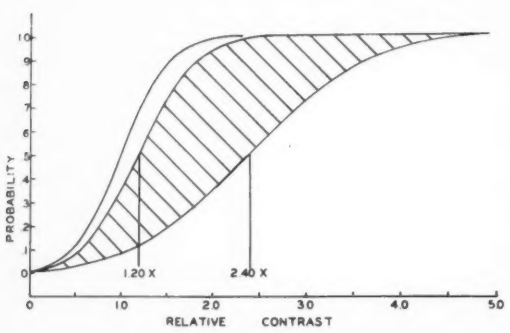

Figure 7.
Data for 77 observers for naive seeing and for practiced performance with the forced choice procedure. The curve to the extreme right of the hatched area represents the average accuracy of naive reporting of detection as a function of target contrast. The single curve to the extreme left is the average accuracy of forced-choice performance after training.

and that needed for forced-choice seeing by highly trained observers is a factor of 2.4. This factor applies at every accuracy level.

In order to correct the data obtained under our original laboratory conditions to apply to dynamic seeing by ordinary observers, we multiply the factors obtained in the Simulator studies by the 2.4 factor. Thus, we obtain factors of 14.4 and 17.4 from the two experiments in the Simulator. It was decided to use a value of 15. This number is designated a "suprathreshold visibility factor," to represent the fact that the visual data are considered to be above the (laboratory) threshold by a factor of 15 in terms of contrast. This factor is used to multiply the contrast values necessary for 99% accuracy in the original laboratory experiments. Thus, we multiply the contrast values presented in Figure 3 for 50% by $1.99 \times 15 = 29.85$. This is accomplished by adjusting the curves in Figure 3 upward by 1.47 on the log contrast axis.

A Device for Equating Practical Visual Tasks To Standard Visual Tasks

The second phase of our research program has been concerned with developing a device for equating the difficulty of various practical visual tasks to standard circular targets, so that the extensive performance data on the standard targets can be used to specify the illumination requirements of the practical tasks. The basic technique we have developed involves varying the contrast of a circular target of four minute diameter until this standard target is equal in difficulty to a given practical visual task.

The equation of the standard and the practical visual tasks is performed under conditions of threshold visibility, since it is practically impossible to equate the difficulty of tasks which are readily visible. The tasks are reduced to threshold visibility by reducing their contrast by superposition of a light veil over the visual task and its surroundings. This light veil is introduced by a variable contrast wedge which reduces the light transmitted from the task and surrounding to the same extent that the light veil is added, thus reducing contrast without altering the adaptational luminance.

The device used to equate the practical and standard visual tasks, known as the Visual Task Evaluator, is shown in Figure 8. The task is placed in front of the device, to the left in the figure, and may be illuminated as desired. The standard circular target is produced within the VTE by means of a lamp, aperture, and projection system. In effect, the initial contrast of the standard target is reduced until both it and the practical task are at threshold visibility when viewed through a contrast reducing wedge.

Figure 8.
The Visual Task Evaluator. Practical tasks of interest are placed in front of the device, to the left in the figure.

The use of the VTE results in a value of contrast for the four minute standard circular target which renders it equivalent in difficulty to each of a series of practical visual tasks of interest. Once these "equivalent contrasts" are available, the luminance requirements for each practical task may be determined from the specification curve shown in Figure 9. The solid curve represents the four minute curve from Figure 3 adjusted by the 1.47 log contrast factor, to make it represent an accuracy level of 99% and a suprathreshold visibility factor of 15. Since the targets were presented for one-fifth second, this curve is considered to represent a level of information assimilation of five APS. The dashed curves represent assimilation levels of one and 10 APS which are presented for the sake of comparison only.

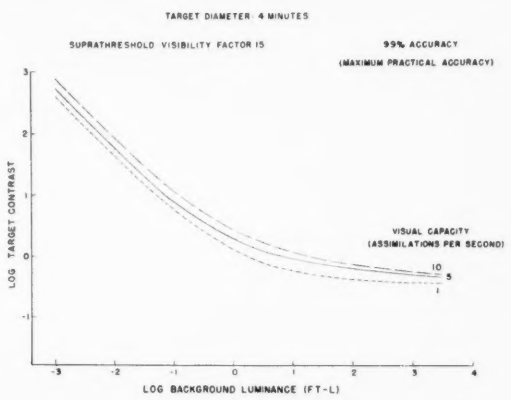

Figure 9.

The specification curve. The solid curve represents the specification curve for the present recommended level of visual capacity of five assimilations per second. This curve is based upon the original laboratory data, corrected to a 99% level of accuracy and corrected to a suprathreshold visibility level of 15 times threshold contrast. The dashed curves for the one and 10 assimilations per second visual capacity level are presented for comparison only. Illumination levels for various practical tasks are determined from the specification curve by a method described in the text.

The specification curve for five APS is used as follows: Each value of the equivalent contrast is converted into a logarithm and is entered at the appropriate location on the ordinate. For each log contrast value, a horizontal line is projected across the figure until it intersects the solid curve. A perpendicular to the abscissa is dropped from each point of intersection. Values of log luminance are thus obtained for each practical task, which represent the log luminance required to bring the various practical visual tasks to the required level of performance. Values of luminance are obtained from the log luminance values, and the illumination levels are then computed from knowledge of the reflectance factors of the general surrounds of the various practical visual tasks.

Sample Illumination Levels for Practical Visual Tasks

It should be of interest to indicate some sample values of illumination requirements obtained with this method. The following were selected to show the wide range of illumination values required for equal performance of various tasks.

Task Description	Illumination Level (foot-candles)
1. 12-point Textype	0.60
2. 6-point Textype	2.98
3. Sample of 6th grade writing with No. 2 pencil	63.0
4. Sample of shorthand copy with No. 3 pencil	76.5
5. Typed carbon, fifth copy	133.
6. Thermofax copy, poor quality	589.
7. Dark brown raised threads on silk	1,680.
8. Pocket stitching, tan shirt	1,890.
9. Broken black thread on spinner bobbin	2,920.
10. Brown thread stitching on brown silk tweed	>10,000.

Acknowledgements

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Daylighting

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The problem of daylighting of buildings is much more complex than is generally realized. This complexity to a large extent is caused by the variability of the building environment, that is, solar radiation, wind velocity, temperature, humidity and the like. Among the various studies of daylighting that have been conducted, those that have considered both the visual and thermal aspects are in the minority. In the research work on daylighting that has been done here major consideration was given to the transmission and control of the luminous components of daylight. Needless to say, there is a great need of a more extensive study of fenestration materials and of the total internal environment of fenestrated buildings.

In general, any daylighting problem is involved with three factors; the intensity and variability of the daylight sources, the overall design of the fenestration and the geometry and reflectivity of the interior to be daylighted. I shall briefly comment on each of these three factors.

The daylight that is incident upon the exterior surfaces of a building may come from three sources; the sun, the sky and by reflection from the ground and surrounding areas. Generally speaking, however, in daylighting design major consideration is given to two extreme conditions; sun and clear sky and an overcast sky. The reason for this is that for sun and clear sky one is principally concerned with control of brightness, whereas, for overcast sky one is concerned with quantity of illumination.

During 1953 and 1954 we conducted an extensive survey of exterior illumination conditions in Ann Arbor. The results of this survey will soon be published by the Illuminating Engineering Society in a paper entitled Studies on Daylight Availability. I shall use a few graphs from this paper to indicate the amount, intensity and variability of daylight that should be considered in planning the daylighting of a building. Figure 1 shows the intensities of illumination for south, east and west vertical surfaces and for a horizontal surface, for sun and clear sky conditions on September 28, 1953. This serves to indicate that the maximum daily intensities, which, of course, vary with the time of year, are upward from 5,000 foot-candles and occur at noon for a horizontal surface and a south vertical surface and during the A.M. and P.M. for east and west vertical surfaces, respectively. If one measures the areas under such curves, 8 A.M. to 5 P.M., for various times of the year and plots them against noon sun altitude the curves of Figure 2 are obtained. These serve to indicate that the most severe conditions for a horizontal surface and east and west vertical surfaces occur during the summer months and for a south vertical surface during the spring and fall. Further analysis of such data shows

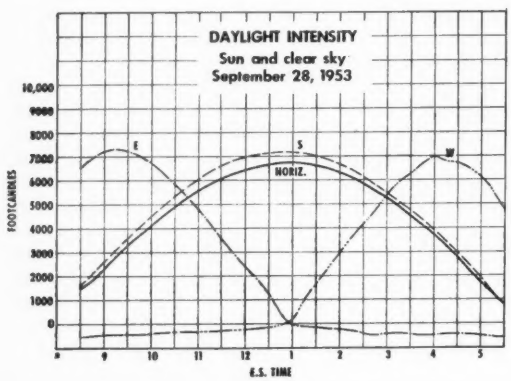


Figure 1

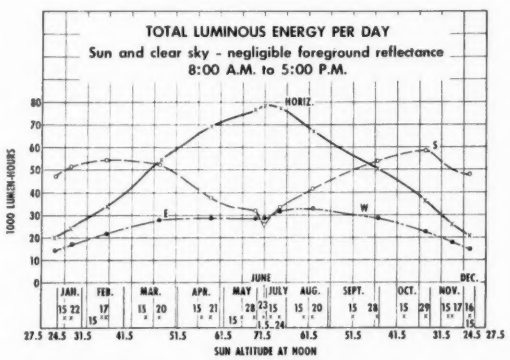


Figure 2

that these maximum conditions for vertical surfaces occur for sun altitudes of 35 to 45 degrees. This fact, at least, should be taken into account in planning a building fenestration. These curves can also be used to estimate the total energy incident on a given surface during any day throughout the year. For this purpose one can use that 1000 lumen-hours is about equal to 35 B.T.U. per sq. ft. per hour.

Possibly of greater interest is the percentage of time, within a certain daily interval, that the exterior illumination of a particular surface is above specific values. Figure 3 presents this information for the school year, 8:30 A.M. to 3:30 P.M. with a foreground reflectance of 25% and takes into account all conditions, cloudy, partly cloudy and clear. If only overcast days are considered then the average vertical surface illumination is 960 foot-candles and the average horizontal surface illumination is 1,670 foot-candles for the same time intervals. If fenestration design is such that minimum acceptable interior illumination is obtained for these average values, then Figure 3 can be used to estimate the percentage of the time when supplementary electric lighting will be required.

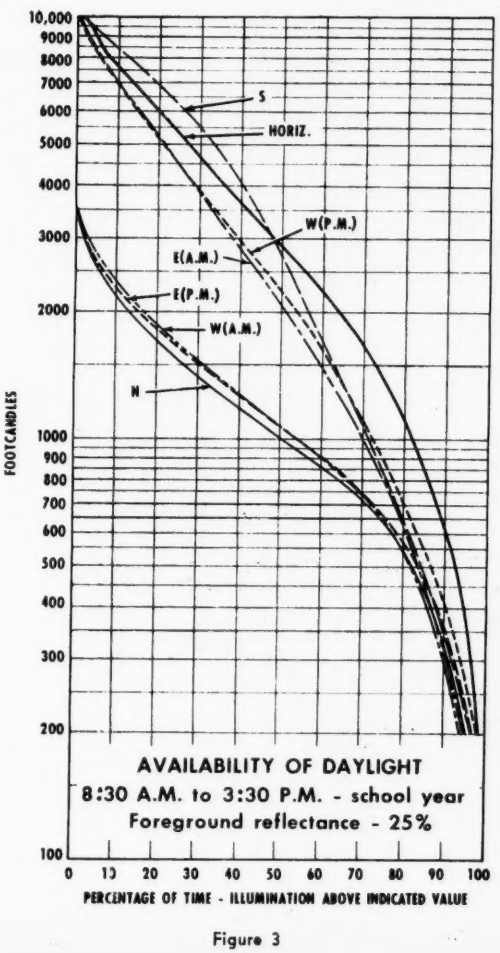


Figure 3

There are a large variety of materials available for use in fenestrations. Table I lists most of these materials with reference to where they are generally used and the range of transmission. They have been divided into two classes, those allowing clear vision to the exterior and those that are obscuring.

The percentage transmission does not in itself predict the effectiveness of the material in providing adequate and acceptable daylighting. In addition it is necessary to have information on the diffusion of light and brightness of the material, or of the views through the material.

In the case of clear vision materials the brightness of the view depends upon the absorption of the glass. Typical maximum exterior brightnesses are: up to 7,000 foot-lamberts for clear sky in the vicinity of the sun, an average of about 2,500 foot-lamberts for an overcast sky, up to 7,000 foot-lamberts for a white building in direct sunlight and the sun has an actual brightness of several hundred million foot-lamberts. Reference to Table I indicates that these brightnesses will be reduced from 10% to about 90% depending upon the material used. However, these materials, because they allow clear vision to the exterior, admit the light from the sun and sky into the interior in a downward direction. This is inefficient from a lighting point of view, since a high percentage of the light is absorbed by the floor, furniture and room occupants before it can be scattered about the

TABLE I.

Fenestration Materials	Use	Range of Transmission[1]
A. Clear Vision		
1. Clear Window Glass	W	90-92
2. Polished Plate Glass	W	90-92
3. Tempered Plate Glass	W	90-92
4. Heat Absorbing Glass	W,S,C	75-83
5. Glare Reducing Glass	W,S,C	45-68
6. Glass Block	Wa	81-85
7. Double Glazing Units	Wa,W	81-85
8. Triple Glazing Units	Wa,W	73-78
9. Wired Glass	W,S,C	72-84
10. Filter Glass	W,V	12½-35
B. Obscuring		
1. Hammered Frosted Heat Absorbing Glass	W,C	36-58
2. Hammered Heat Absorbing Glass	W,C	53-63
3. Wired Heat Absorbing Glass	W,S	—
4. Frosted Glass	W	63-76
5. Patterned Glass	W,C	52-92
6. Double Glazing Units	Wa,W	56-76
7. Patterned Sandblasted Glass	W	36-77
8. Prismatic Glass Block	Wa,C	40-50
9. Diffusing Glass Block	Wa,C,R	40-50
10. Decorative Glass Block	Wa	70-80
11. Solar Selecting Glass Block	Wa,Rs	20-30

Code: W - Windows
Wa - Walls
C - Clerestories, monitors and saw-tooth
S - Skylights
R - Roof-panels
Rs - Prefabricated roof-panels
V - Vision strips
[1]Per cent - Normal Incidence

room and, in addition, high intensities on some of the room surfaces may cause reflected glare.

Whereas clear vision materials provide little or no diffusion for the transmitted light, the obscuring materials are designed to provide a wide range of diffusion patterns. In these cases, since the brightness is related to the material rather than the exterior view, it is necessary to refer directly to the amount of light incident on the exterior.

As an illustration of how increase of diffusion reduces maximum brightness, consider two sheets of obscuring material, one being a perfect diffuser and the other an average obscuring material, each transmitting 55% of the light that is incident normally in a collimated beam. The brightness distribution of each material, per 1,000 foot-candles of incident illumination, is shown by Figure 4.

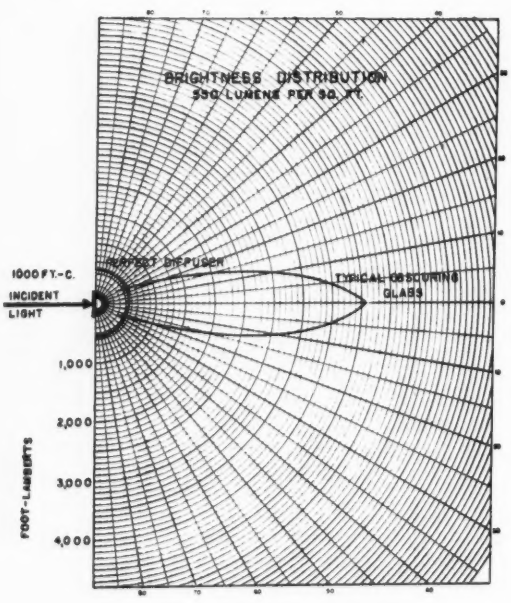


Figure 4

It is apparent that the smaller the angle of scattering the greater the maximum brightness per lumen of transmitted light. One observes that the ratio of maximum brightness of the average obscuring material to that of the perfect diffuser is about 8.4 to one. The perfect diffuser is simply used to show the extent to which brightness can be reduced by an increase in diffusion; actually there is no material manufactured that can be classified as a perfect diffuser, although solid opal glass and diffusing glass block are "near" perfect diffusers. As regards the magnitude of the brightness for direct sunlight, for an incident illumination of 9,000 foot-candles a brightness of 40,000 foot-lamberts is easily obtainable with some obscuring materials. For prismatic glass block incorporating specific control prisms a maximum brightness of 2,000 foot-lamberts is typical.

For purposes of comparing performance, consider that the fenestration materials can be divided into three classes; clear vision, typical obscuring and prismatic glass block. It is impossible in a paper of this length to give detailed information on the daylighting that results when each of these materials is considered in connection with the many different fenestration arrangements employed in the various types of buildings. One way to present relative performance of the three types of materials is to consider each of them as constituting a fenestration in a particular building type.

One of the most common interiors is the unilaterally daylighted room. Such a room is shown by Figure 5 where the fenestration is considered to occupy the upper half of the outside wall and the room depth is equal to twice the ceiling height. For any type of fenestration material the amount of daylight reaching any point on the working plane can be considered in two parts; the direct light from the fenestration and the multiplied light reflected from the room surfaces. Various methods have been developed that allow the calculation of each of these two components.

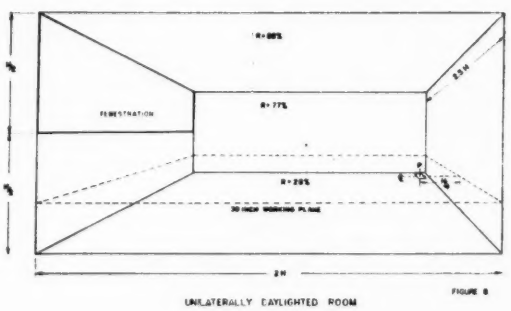


Figure 5

In any daylighted interior reference is usually made to the poorest lighted task and the brightness of the fenestration as viewed from that task. In Figure 5 consider that P is such a task. According to the theory of surfaces sources, if the fenestration has an average brightness of B foot-lamberts and all the remainder of the room surfaces above the working plane have an average brightness of B′ foot-lamberts, as viewed from P, then the illumination at P is given by $E = 0.025\ B + 0.975\ B'$ (FtC).

Some evaluation of the quality of the daylighting can be obtained from the ratios B/E and B/B′; the lower the ratios the higher the quality of the lighting, In giving the comparative figures

for the three general types of fenestration materials, and for a "near" perfect diffuser, it has been assumed that the average value of B is the same for each, namely 1,000 foot-lamberts. On this basis, the results are as appear in Table II.

TABLE II.

Material	0.025B	E	B′	B/E	B/B′
Clear Vision	25 Ft. C	65 Ft. C.	41 Ft. L	19	31
Typical Obscuring	25	45	21	28	60
Prismatic Block	25	105	82	10	12
"Near" Perfect Diffuser	25	95	72	13	17

The figures for the clear vision materials are typical for exterior conditions not involving direct sunlight. The remaining figures are typical for direct sunlight.

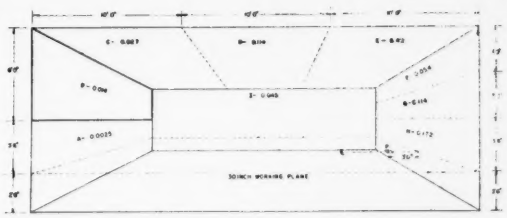
Since the "observer" brightness is the same in each case, these data serve to show the effect that the brightness distributions pattern of the fenestration material has on the quality of the lighting; the "near" perfect diffuser with a uniform distribution of brightness and prismatic glass block with maximum brightness in directions toward the ceiling and upper walls giving the higher quality daylighting. It will also be observed that the increase in illumination due to multiple reflections is greater in the cases of better diffusion. It is obvious that as room surface reflectances decrease the value of E will decrease toward 25 foot-candles, which is the value for zero reflectance, and the values of B/E and B/B′ will increase.

In order to make these figures more realistic as regards quantity, consider an average overcast sky condition for two cases, clear flat glass and prismatic glass block. For an overcast sky that provides 1,000 foot-candles on the exterior of the fenestration, B = 1,250 for clear flat glass and 300 for a common type of prismatic glass block; consequently E = 81 foot-candles for clear flat glass and 31 foot-candles for the block. It is obvious that the prismatic glass block, a particular form of obscuring material, provides lower fenestration brightness and lower brightness ratios at the expense of quantity of illumination. What this means in terms of service period can be determined by referring to the curves of Figure 3.

The unilaterally daylighted room is only one of the many that are in actual use. It is impossible to discuss in detail the complete fenestration systems utilizing the various types of secondary fenestrations, such as, clerestories, monitors, saw-tooth units and skylights. However, Figure 6 indicates a common classroom interior wherein the room is square and has a depth equal to 2.5 times the ceiling height. The specific dimensions can, for the most part, be ignored in this consideration. The room surfaces have been divided into specific sections, as designated by A-I, and a factor has been calculated for each section which is the ratio of the illumination at P (F t C) to the average brightness (F t L) of the section as viewed from P. These factors, or portions of them, can be used to evaluate the effect of placing secondary fenestrations in various locations to raise the minimum illumination and consequently improve the quality of the daylighting in rooms that would be inadequately daylighted with only a main fenestration.

Generally sections A and B constitute a main fenestration. Clerestories have been used, having a position such as section F, or a position with opposite exposure such as between E and D when E is at a greater height. More recently, because of lower costs and simpler construction, ceiling panels consisting of solar-selecting and diffusing glass block and skylights glazed with various types of obscuring glass and plastic base have been used in areas similar to section E.

From a daylighting point of view, ceiling panels have several advantages over a clerestory



COMMON CLASSROOM INTERIOR

Figure 6

arrangement. Clerestories receive their light from only half the total sky, whereas, ceiling panels are exposed to the entire sky. Thus, the transmission of light through the latter is much more uniform, in general, over a period of one day or one year. Also, on an overcast day, the exterior illumination of a horizontal surface is about twice that of a vertical surface.

As can be seen from Figure 6 there is another advantage of the ceiling panel in that the illumination factor for section E is substantially larger than for section F. In fact, the illumination factor for section E is too large, so in practice, only a portion of E is used as a ceiling panel.

I have only briefly discussed some of the factors involved in the luminous phase of daylighting. Most of the faults of daylighting, as it is practised today, relate to the thermal aspect. As I remarked at the start more research is required on the absorption and transmission of solar heat by fenestration materials and the effects on the interior thermal environment.

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Making a Lighting Survey

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The material presented here represents the efforts of a joint subcommittee of the IES and USPHS, under the chairmanship of J. F. Parsons, Buffalo 3, New York. This joint subcommittee was assigned the task of preparing a manual on the subject "How to Make an Eye Conservation Survey," including not only the engineering phases of the subject, but the medical as well. Their work is now completed, but publication of the report is held in abeyance until funds become available.

The history of this committee may be of interest to you. In 1946 I was devoting full time to studying illumination problems for the Public Health Service in Washington, D. C. My contacts with industrial hygiene personnel indicated to me the need for a readily available pamphlet on how to make lighting surveys. Likewise, it was felt that a readily available reference pamphlet, providing current information on eye testing practices, would be valuable to the company physician. In addition to these two interested groups, I thought it would be well to expose the illuminating engineer to some of the procedures and practices of the industrial hygienist. For these reasons I contacted C. L. Crouch, Technical Director of Illuminating Engineering Society, requesting that the next time he was in Washington he come and discuss the matter with me. Shortly after that the committee was formed, and some of its work is now presented.

The probability of error in making foot-candle measurements in the field is relatively high, even when the recorder is experienced. In order to achieve an acceptable degree of accuracy in such field measurements, Survey Form A was developed by the Committee. The Illuminating Engineering Society Standard Method and Survey Form (IS-10) was used extensively in drafting this form.

The following comments on possible sources of error in a survey should be considered when making illumination measurements so that errors within the control of the surveyor can be minimized and accuracies will not be expected that are beyond the limitations of the instruments used.

As the visual environment is affected not only by the illumination level but by the brightness distribution in the field of view, it is important to enter carefully as completely as possible all the data outlined in Survey Form A.

In using illumination measuring instruments, the cell must be unobstructed by the observer when taking the readings from which the average illumination is to be determined. When measuring spot illumination values at the point of work with the worker in place, assume the worker's position as closely as possible, regardless of possible shading of the cell. Place the cell at the point of work and in the plane of the work. Take measurements under the general lighting only and then with supplementary lighting added. White or light upper clothing should not be worn unless the worker is customarily so attired. Reflections from light colored clothing may increase the reading.

Changes in the light output of lamps owing to voltage variations, hours of burning and dust and dirt depreciation, make it desirable to report illumination measurements under the actual conditions found. These conditions should be noted on the Survey Form A.

Seasoning Period: With incandescent filament lamps, seasoning is almost instantaneous. However, with gaseous-arc sources, particularly the fluorescent type, such seasoning requires not less than 100 hours of operation before stabilization at rated initial output. The average excess output during the initial 100 hour period is 10% or more above the rated initial output of the lamps. No reading should be recorded for gaseous source systems unless they have been operated at least 100 hours.

Temperature: The light output of gaseous-arc sources, particularly fluorescent lamps, varies with ambient temperature, decreasing appreciably from design values if the temperature adjacent to the lamps rises above certain limits. These limits are often exceeded in operating luminaires, resulting in a decrease of light output during the first half hour of operation. For this reason, no readings should be taken with a gaseous source system until it has been in operation for at least half an hour.

Average Horizontal Foot-candles

The purpose of the readings outlined in Table V of Form A and the subsequent calculations described in the Operational Procedure is to arrive at the average horizontal foot-candles of the entire area, usually at a height of 30 inches above the floor. The method employed to obtain the average is that of the familiar flux-of-light method in which the average foot-candles in an area is the quotient of lumens on the working plane by the area in square feet; lumens on the working plane being arrived at by the summation of the products of the foot-candles in representative portions of the area by the individual area of each portion. The standard method for obtaining the average illumination is a time saving procedure which looks complicated but is essentially very simple. It comes within 10% of the accuracy obtained by the laborious method of marking the area off into two-foot squares, reading the illumination in each square and averaging it.

Brightness Measurements

From the viewpoint of effectiveness and comfort of the visual environment in critical seeing areas, the brightness distribution in the field of view is at least as important as the illumination level. In addition to the brightness of the task itself, the brightness of the immediate surroundings has influence on the ease of seeing. In the peripheral field beyond the total 60° cone of central vision, unusually high or low brightness, changing brightness or color, may be distracting and fatiguing.

The visual environment cannot be appraised by casual inspection unless some outstanding factors detrimental to seeing are present. Luminaires with insufficiently shielded lamps; low levels of illumination; dark, glossy walls or ceilings; dark, shiny work surfaces, etc., are examples of such obviously poor conditions. Appraisal of seeing conditions in any work area is far more trustworthy when observed over a prolonged period. A large area of sky, for example, may to the casual observer be of no importance. It may even be a pleasant attraction but it may be a very annoying source of glare when seen in the peripheral field of view during the long hours of the working day. The same sky at night may be a source of annoying contrast because of its low brightness. A well designed and acceptable luminaire may be a glare source when viewed against a dark wall or ceiling at which brightness readings might be taken.

The brightness contrast between the visual task (such as book type) and its immediate background (such as the book page) is one of the factors which determines the degree of ease with which the task is seen. The higher this contrast the greater the ease of seeing. The brightness-ratios between the immediate surround (such as the book page) and the rest of the visual field determines the quality of the visual environment. Low brightness ratios throughout the entire field of view are desirable.

Brightness ratios may vary widely from day to night operations. If areas being surveyed are used for both day and night operations, brightness surveys preferably should be made during both periods to evaluate properly the seeing conditions encountered.

A comprehensive survey should, therefore, include at least a qualitative evaluation of the brightness distribution as seen by a variety of workers at different times during their working period.

Typical measurements useful in evaluating the brightness pattern of the visual environment are given in Table VII of Form A. Measurements and comments of this nature are an essential part of the lighting survey. The most convenient procedure for obtaining maximum brightnesses of the luminaire in the various zones is to take them from a photometric test report of the luminaires. Such reports should be made by a reliable laboratory.

OPERATIONAL PROCEDURE FOR USE OF FORM A
EYE CONSERVATION SURVEY
ILLUMINATION

Company: Give name and address of firm

Contact: Give name and title of individual through whom arrangements were made for this survey

Survey by: Record name, title and affiliation of surveyor

Area surveyed: Describe for future identification, giving name of area and, if applicable, building and room numbers

DESCRIPTION OF ILUMINATED AREA

Type of Work Performed: Describe the work performed and classify the visual task as: rough, casual, ordinary, difficult and critical, very difficult, or most difficult.

Sketch: Make a sketch of the area. Show dimensions, including ceiling height, in feet and inches. Show location of windows and exposure (N, S, E or W). Indicate entrances and chief orientation of occupants, if any.

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Texture: Record texture of surfaces as gloss, semigloss, mat.

Color: Use the following as a guide in describing colors:

Color		*Modifier*
Pink	Green	Light
Red	Blue	Dark
Orange	Purple	Medium
Brown	White	
Yellow	Gray	
Tan	Black	
Olive		

Reflectances: Record in percent. Estimate reflectances of colored surfaces by comparison with the "Munsell Value Scales for Judging Reflectances."

Condition: Record general cleanliness of interior as clean, average or dirty.

DESCRIPTION OF GENERAL LIGHTING SYSTEM

Hours Used: Record this figure on the basis of day to day usage. Include the use of the lighting after regular hours by maintenance personnel.

Number: Luminaires.

Luminaire Wattage: Record wattage of the individual luminaires. The total wattage of an incandescent filament luminaire is the total wattage of the lamps. The total wattage of a fluorescent or mercury luminaire is the total wattage of the lamps plus the wattage of the auxiliaries (ballast or transformers).

Light Sources: Record in Table II whether the equipment is: incandescent filament, fluorescent, mercury, or a combination.

Distribution Classification: Determine by inspection as outlined below, or if this does not appear feasible, obtain from the manufacturer's catalogue data.

Classification	% Total Light Emitted Above *Horizontal*	% Total Light Emitted Below *Horizontal*
Direct	0-10	100-90
Semi-indirect	10-40	90-60
General Diffuse and Direct-Indirect	40-60	60-40
Semi-indirect	60-90	40-10
Indirect	90-100	10-0

Luminaire Description: Give manufacturer's name, catalogue number and any other information required for a positive indentification of the luminaire. Give a general description of the luminaire such as open industrial, glass side panels, open top, louvered bottom, etc. Give number and type of lamps employed per luminaire; such as, for incandescent filament, clear, inside frost, silvered bowl, projector or reflector, etc.; for fluorescent, bipin, single pin, diameter, length, etc. For single pin fluorescent lamps give operating current as stated on the luminaire ballast. Use space at end of Form A if necessary for complete description.

Luminaire Spacing: Indicate on the sketch of the area the arrangement and spacing of the luminaires in feet and inches. Note any irregularities in the general pattern.

Type of Mounting: Recessed, semirecessed, surface, suspended.

Mounting Height (MH): Record feet and inches from floor to bottom of direct or semidirect luminaires. Record in inches the overall suspension of luminaires other than direct or semidirect.

Condition: Record whether lamps and luminaires are clean, average or dirty, and whether lamps are markedly blackened.

Voltage of Lamps: Record the rated voltage of incandescent filament lamps which is etched on the bulb.

Full Load Voltage: With the full load on, record one voltage reading near the lighting panel and a second reading at the point farthest from the panel. Consideration should be given to the fact that the voltage during working hours may be considerably lower than at the time illumination measurements are taken. If the variation in voltage is such as to substantially reduce the illumination during working hours, such fact should be noted under "Comments" and given consideration in the final evaluation of the lighting installation.

Color of Lamps: This characteristic is etched on the fluorescent lamp tube. Other color descriptions are: straight mercury; color improved mercury; straight incandescent; daylight incandescent; tinted incandescent; etc.

DESCRIPTION OF SUPPLEMENTARY LIGHTING

Item No.: Assign item numbers to the various types of supplementary luminaires used in the area.

Work Surface Lighted: Machines, desks or other equipment on which each type of supplementary luminaire is used.

Number: Give the number of supplementary luminaires of each type used in the area.

Lamp: Record wattage, color and type of lamp.

Luminaire Description: Give manufacturer's name and catalogue number if available. Describe as to physical construction and adjustments provided. Give direction of light on work and distances of luminaire from work. Record whether lamp is concealed from view of workers.

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Condition: Record whether luminaire is clean and in good operating condition.

Item Details: Record any other details by item number which seem important. If supplementary luminaires provide aids to seeing other than increased illumination, give description.

INSTRUMENTS USED

Caution: For measuring illumination use cell type instruments which are cosine and color corrected. They should be used at a temperature above 60° if possible. Expose the cells to the approximate illumination level to be measured until it becomes stabilized before taking readings. This usually requires five to 15 minutes. A mercury or fluorescent system must be lighted for at least one-half hour before measurements are taken to be sure that normal operating output has been attained. In relatively new lamp installations at least 100 hours of operation of a gaseous source must elapse before measurements are taken.

ILLUMINATION MEASUREMENTS IN AREA

Foot-candles on a Horizontal Plane 30" Above the Floor from General Lighting Only:

General: Position the measuring instrument so that when readings are taken the surface of the light sensitive cell is in a horizontal plane and 30 inches above the floor. This can be facilitated by means of a small portable stand of wood or other material that will support the cell at the correct height and in the proper plane.

Exclude daylight during illumination measurements. Take readings at night or with shades, blinds or other opaque covering on the windows and/or skylights.

Readings are not to be obstructed by surveyor or worker.

Select from Tables I through V in Form A the table suited to the area and fill in the foot-candle values required.

Measurement Procedure in a Regular Area with Symmetrically Spaced Luminaires in Two or More Rows (See Table V and Figure 1).

Step 1 in Table V

Measure and record readings taken at stations r-1, r-2, r-3 and r-4 for a typical inner bay.

Measure and record readings taken at stations r-5, r-6, r-7 and r-8 for a typical centrally located bay.

Total and determine average of "r" readings. Call average "R" and record.

Step 2 in Table V

Measure and record readings taken at stations q-1, q-2, q-3 and q-4 of typical half-bays on each side of room.

Total and determine average of "q" readings. Call average "Q" and record.

Step 3 in Table V

Measure and record readings taken at stations t-1, t-2, t-3 and t-4 of typical half-bays on each end of room.

Total and determine average of "t" readings. Call average "T" and record.

Step 4 in Table V

Measure and record readings taken at stations p-1 and p-2 for two typical corner quarter bays.

Total and determine average of "p" readings. Call average "P" and record.

Step 5 in Table V

Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{R(N-1)\ (M-1) + Q(N-1) + T(M-1) + P}{NM}$$

Obtain values of R, Q, T and P from Table V.

N = Number of luminaires per row.

M = Number of rows.

Record average illumination for area at bottom of Table V.

Measurement Procedure in a Regular Area with a Single Row of Individual Luminaires (See Table V(a), Figure 2).

Step 1 in Table V(a)

Measure and record readings taken at stations q-1, q-2, q-3, q-4, q-5, q-6, q-7 and q-8 for four typical half-bays located two on each side of the area.

Total and determine average of "q" readings. Call average "Q" and record.

Step 2 in Table V(a)

Measure and record readings taken at stations p-1 and p-2 for two typical corner quarter-bays.

Total and determine average of "p" readings. Call average "P" and record.

Step 3 in Table V(a)

Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{Q(N-1) + P}{N}$$

Obtain values of Q and P from Table V(a).

N = Number of Luminaires.

Record average illumination for area at bottom of Table V(a).

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Measurement Procedure in a Regular Area with a Symmetrically Located Single Luminaire (See Table V(b) and Figure 3).

Step 1 in Table V(b)

Measure and record readings taken at stations p-1, p-2, p-3 and p-4 for all four quarter-bays.

Total and determine average of "p" readings. Call average "P" and record.

Step 2 in Table V(b)

Average illumination equals "P".

Record average illumination for area at bottom of Table V (b).

Measurement Procedure in a Regular Area with Two or More Continuous Rows of Luminaires (See Table V(c) and Figure 4).

Step 1 in Table V(c)

Measure and record readings taken at stations r-1, r-2, r-3 and r-4 located near the center of the area.

Total and determine average of "r" readings. Call average "R" and record.

Step 2 in Table V(c)

Measure and record readings taken at stations q-1 and q-2 located at each midside of the room and midway between the outside row of luminaires and the wall.

Total and determine average of "q" readings. Call average "Q" and record.

Step 3 in Table V(c)

Measure and record readings taken at stations t-1, t-2, t-3 and t-4 at each end of room.

Total and determine average of "t" readings. Call average "T" and record.

Step 4 in Table V(c)

Measure and record readings taken at stations p-1 and p-2 in two typical corners.

Total and determine average of "p" readings. Call average "P" and record.

Step 5 in Table V(c)

Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{RN(M-1) + QN + T(M-1) + P}{M(N+1)}$$

Obtain values of R, Q, T and P from Table V(c).

N = Number of luminaires per row.

M = Number of rows.

Record average illumination for area at bottom of Table V(c).

Measurement Procedure in a Regular Area with a Single Row of Continuous Luminaires (See Table V(d) and Figure 5).

Step 1 in Table V(d)

Measure and record readings taken at stations q-1, q-2, q-3, q-4, q-5 and q-6.

Total and determine average of "q" readings. Call average "Q" and record.

Step 2 in Table V(d)

Measure and record readings taken at stations p-1 and p-2 in typical corners.

Total and determine average of "p" readings. Call average "P" and record.

Step 3 in Table V(d)

Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{QN + P}{N + 1}$$

Obtain values of Q and P from Table V(d).

N = Number of luminaires.

Record average illumination for area at bottom of Table V(d).

Spot Foot-candles at Point of Work and in Plane of Work

General: Position the measuring instrument so that when readings are taken the surface of the light sensitive cell is in the plane of the work or of that portion of the work on which the critical visual task is performed, horizontal, vertical or inclined. Record work position in Table VI.

Take readings at night or with windows and/or skylights covered.

Take readings with workers in normal working position.

Point 1 is work point in area where, with worker in place, the maximum total illumination (local plus general) was found. Record this value. Describe work point.

Point 2 is similar location where minimum total illumination was found. Record this value. Describe work point.

Points 3 through 6 are other representative work points throughout the area. Record these values. Describe work points.

Foot-lamberts (Brightness) from Specified Work Point Locations

General: Foot-lambert surveys, unlike foot-candle surveys, are to be made under actual working conditions with the combinations of natural and artificial lighting facilities available. Consideration should be given sun position and weather conditions, both of which may have marked effect on brightness distribution. All lighting in the area, both general and supplemental, should be in normal use. Work

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areas used only in the daytime should be surveyed in the daytime; work areas used both daytime and nighttime should preferably have two brightness surveys made under the two sets of conditions, as the brightness distribution and the possible comfort or discomfort will differ markedly at these times. Nighttime surveys should be made with shades drawn. Daytime surveys should be made with shades adjusted for best control of daylight.

Read the instructions for using the brightness measuring instrument employed if not familiar with its use. Take practice readings to acquire facility in balancing the brightness of the instrument fields before making the survey.

Check the dial pointer on the instrument frequently during the survey and keep the pointer on the index mark by adjusting the rheostat knob. If appreciable intervals of time must intervene between readings, it is well to turn off the comparison lamp in the instrument.

On the floor plan sketch of the area, indicate which exterior wall or walls, if any, were exposed to direct sunlight during the time of the survey by writing the word Sun in the appropriate location.

Measurement Procedure: Refer to Table VII. Take the worker's position at Work Point A. Locate Point A and the direction of view by an arrow and a letter on the sketch. Aim the instrument at a luminaire which occurs at about 45° above eye level in the direction the worker faces. Balance the brightness of the instrument fields. Record the reading in foot-lamberts.

Remaining in the same position, repeat this operation on a luminaire which occurs at about 30° above eye level. Record this reading.

Remaining in the same position, repeat this operation on a luminaire which occurs at about 15° above eye level. Record this reading.

Remaining in the same position, take a reading at a point on the ceiling just above a nearby luminaire. Record this reading.

Remaining in the same position, take a reading at a point on the ceiling midway between two nearby luminaires. Record this reading.

Remaining in the same position, take a reading of the ceiling or upper wall at a point apparently immediately adjacent to the luminaire at 15° above eye level previously measured.

Remaining in the same position at location A, proceed with the remaining measurements itemized in Table VII. Record all of these readings.

If there are window shades, draw them and read the brightness. If there are no shades, read the brightness of the window glass or of the visible scene seen through it.

Task — the work itself, paper, metal or other material worked on.

Immediate surroundings — the pad, desk top, bench top or other surface immediately adjacent to the work within a 60° cone seen by the worker when working on the task.

Peripheral surroundings — the surroundings outside the 60° cone seen by the worker when working on the task.

Select by visual inspection the highest brightness in the entire field of view of the worker; measure and record it together with a brief description of its nature and location with respect to the worker.

Describe source of the highest brightness as: general lighting luminaire, local lighting luminaire, window, etc.; so many degrees to right or left, so many degrees above horizontal.

Assume successively the other locations B through F, taking as many of these positions as may be required to obtain a representative survey of the brightness distribution. Repeat all measurements and recordings outlined above, including showing locations and orientations on the sketch.

On the completion of the measurements, switch off the lamp on the meter by turning the switch to "off."

Daylighting

Daylighting Means: Record facilities provided for this purpose, such as windows or skylights, and describe briefly, such as: large windows on two opposite walls occupying about_____percent of total surface of these walls; or saw-toothed skylight_____feet by _____feet at_____foot intervals; or monitor roof with two rows of_____foot high windows, etc.

Daylight Control Means: Record facilities provided for this purpose, such as configurated or painted window glass, directional or diffusing glass blocks, curtains, shades, blinds, etc.

Maintenance

Lamp Replacement: Record whether lamps are replaced individually as they burn out, or whether they are replaced as a group at certain intervals.

Percentage of Burnouts: Estimate the percentage of inoperative lamps in terms of the total number of lamps in the general lighting system.

Painting Schedule: If there is a regular painting schedule, record yearly interval between paintings. If there is no painting schedule, so record. If painting is impracticable, as it might be in foundries or other heavy industries, record "impracticable."

General Observations On The Visual Environment

All lighting in the area, both general and supplementary, is to be in normal use. Assume successively the worker's positions A through F in Table VII, and record your personal reactions to the various conditions experienced. Remain in at least three of these positions for several minutes before recording your impression. Assume the worker's role as closely as possible, including the positions, the motions of the hands and the work. Imitate as far as feasible the visual habits of the worker, looking intently at the work for one or two minutes, momentarily glancing up from time to time and then again attentively regarding the work point.

Daylighting Surveys

While the treatment of the other sections of this presentation has been primarily from the viewpoint of appraising artificial lighting systems, the following short discussion on daylighting surveys has been included for those concerned with this phase of illumination.

Careful fenestration planning and material application will provide effective brightness control and at the same time ensure good daylight utilization in buildings of all types in almost any location.

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To compare and evaluate the effectiveness of various day-light control devices such as light-diffusing and light-directing glass blocks, roller shades, draw drapes, venetian blinds and exterior louvers, a different survey technique is employed than that ordinarily used in checking electric lighting installations.

It is usually desirable, for example, to compare performance under each of three different exterior conditions: 1. Overcast Day 2. Clear Day - no sun on fenestration 3. Clear Day - sun on fenestration.

The practical daylight brightness control problem in any interior varies with the azimuth and altitude of sun and is influenced by the reflectance of metal roofs, snow cover, nearby building and natural obstacles. On elevations not exposed to direct sunlight, cloud brightness (often as high as 5,000 foot-lamberts) must be controlled.

Because of these variables, a complete report on fenestration performance should include, in addition to specific illumination and brightness measurements, some statement regarding performance in winter, summer, spring and fall.

Interior illumination and brightness may be considered to vary directly in proportion to the exterior illumination of the fenestration, the fenestration area and interior surface reflectance. Thus, the more light outside, the larger the fenestration area; and the higher the interior reflectance, the higher the levels will be inside.

The following daylighting survey technique provides means for correcting for the important variables. Data obtained in this manner will provide reliable means for checking design predictions and comparing different types of fenestration.

Instrument Set-Up

Photocells must be color and cosine corrected. (Daylight color varies widely and much light from some types of unilateral fenestration enters at near grazing angles.) Cell No.1 and meter No.1 should cover the range 250-8000 foot-candles. Meter No. 2 should cover range 10-300 foot-candles. Meter No. 3 should cover range 5-500 foot-candles.

1. "Control" Readings
   a. Mount fixed photocell No. 1 in vertical exterior plane of fenestration. Connect to foot-candle meter No. 1 (inside room) by long lead wires.
   b. Mount fixed photocell No. 2 in horizontal plane 30 inches above floor at center point of room and connect to foot-candle meter No. 2 located for convenient simultaneous reading with meter No. 1.
2. Performance Data
   a. Mount photocell No. 3 in horizontal plane 30 inches above floor on a movable platform, tripod or other level surface. Connect by long lead wires to foot-candle meter located for convenient simultaneous reading with meters 1 and 2.
   b. Mount fixed brightness meter 42 inches above floor on centerline of room two-thirds distance from front to rear walls. In order to obtain accurate readings, this meter should be on a transit tripod, pan-head tripod or other steady universal mount.

Procedure

1. Brightness Readings
   Brightness observer aim brightness meter at first of series of at least 27 predetermined points in field of view on: fenestration, ceiling, front, inside and outside walls and floor. (Points to provide reasonable coverage of each surface.) Balance meter and read brightness; recorder simultaneously reads foot-candle meters 1, 2 and 3; records one brightness value and three illumination values.
2. Illumination Readings
   Movable photocell No. 3 should be placed at first of series of nine predetermined stations in room. A simultaneous meter No. 3 reading should be recorded for each brightness balance. Move cell to station two before next brightness reading. (Result: For each run, three readings at each illumination station if brightness is measured at 27 points.)

For best results, work should proceed rapidly to minimize continuous variation in exterior conditions.

Analysis And Report

Analysis: Determine the average meter No. 1 reading during the run. Let this meter reading represent the average fenestration illumination and procedure as follows to adjust all other readings to agree:

a. Determine average meter No. 1 to meter No. 2 ratio. Divide average fenestration illumination by this value to obtain average midroom illumination.
b. Multiply each meter No. 3 reading recorded and each brightness value recorded by the average midroom illumination and divide by the simultaneous meter No. 2 reading to obtain the value corresponding to the average fenestration illumination.

Report: Date, time and location of Survey;
Room dimensions, fenestration details and dimensions, orientation of fenestration wall, local obstructions if any, daylight controls, surface reflectance.
Average Exterior Illumination of Fenestration: Sun, azimuth and altitude with respect to a line perpendicular to the plane of the fenestration. Weather conditions.

References

The following references were consulted in preparing the preceding work:

Making The Lighting Survey

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4. Guide for Lighting Data Sheets and Lighting Problems. IES reprint from *Illuminating Engineering*. September, 1946, Illuminating Engineering Society.

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5. HIGBIE AND BULL: How Glass Affects Your Daylighting. *Illuminating Engineering*, March, 1931.
6. IVES, KNOWLES AND THOMPSON: Studies in Illumination IV - Daylight in Buildings. *Public Health Bulletin* 218, April, 1935, U. S. Treasury Department, PHS.
7. BROWN: Control of Natural Light in School Rooms. *Illuminating Engineering*, March, 1940.
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9. BIESELE, FOLSOM AND GRAHAM: Control of Natural Light in Classrooms. *Illuminating Engineering*, September, 1945.
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11. BIESELE: Daylight in Classrooms. *Illuminating Engineering*, July, 1950.

FORM A.
EYE CONSERVATION SURVEY
ILLUMINATION

Company .....

Contact .....

Survey by .....

Area Surveyed ..... Data..... Time ..... AM-PM

DESCRIPTION OF ILLUMINATED AREA

Type of work performed in area .....

.....

Length .....Width .....Height .....Temperature .....°F.

TABLE I.

Surface	Material	Texture	Color	Reflectance	Condition
Ceiling					
Walls					
Dado					
Trim					
Floor					
Window Shades ..					
Work Surface					
Equipment					

TABLE II.
DESCRIPTION OF GENERAL LIGHTING SYSTEM

LUMINAIRES

No.	Wattage	Light Source	Distribution	Description	Spacing	Mounting	M. H. or Susp.	Condition

Date of installation ..... Approximate hours used since installation _____

Rated voltage of inc. lamps ..... Full load voltage (1)..... (2)..... Color of lamps _____

TABLE III.
DESCRIPTION OF SUPPLEMENTARY LIGHTING
SUPPLEMENTARY LUMINARIES

Item No.	Work Surface Lighted	No. of Luminaires	Luminaire Distribution	Lamp Watts-Type	Luminaire Description Location & Mounting	Condition
1						
2						
3						
4						

Item Details: _____

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TABLE IV.
INSTRUMENTS USED

Measurement	Manufacturer	Name	Model	Last Calibration Date	By
Illumination					
Brightness					
Reflectance					
Color					
Voltage					

TABLE V.
ILLUMINATION MEASUREMENTS IN AREA
Regular Area With Symmetrically Spaced Luminaires in Two or More Rows

Step 1		Step 2		Step 3		Step 4	
Station	Ft-c	Station	Ft-c	Station	Ft-c	Station	Ft-c
r-1		q-1		t-1		p-1	
r-2		q-2		t-2		p-2	
r-3		q-3		t-3			
r-4		q-4		t-4			
r-5		q-5					
r-6		q-6					
r-7		q-7					
r-8		q-8					
Total	—		—		—		—
(Aver.) R =		Q =		T =		P =	

Step 5: Average illumination on plane 30" above floor = _____ Ft-c (I.E.S. Standard Method)

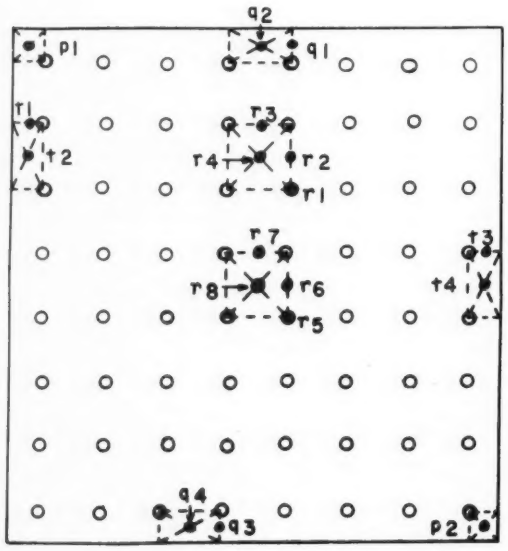

Figure 1.
Measurement procedure in a regular area with symmetrically spaced luminaires in two or more rows.

TABLE V (a).
REGULAR AREA WITH SINGLE ROW OF INDIVIDUAL LUMINAIRES

Step 1		Step 2	
Station	Ft-c	Station	Ft-c
q-1		p-1	
q-2		p-2	
q-3			
q-4			
q-5			
q-6			
q-7			
q-8			
Total	—		—
(Aver.) Q =		P =	

Step 3: Average illumination on plane 30" above floor = _____ Ft-c (I.E.S. Standard Method).

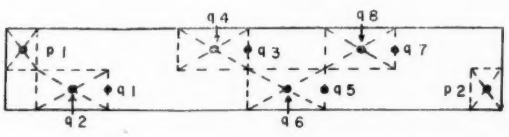

Figure 2.
Measurement procedure in a regular area with a single row of identical luminaires.

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TABLE V (b).
REGULAR AREA WITH SYMMETRICALLY LOCATED SINGLE LUMINAIRE

Step 1	
Station	Ft-c
p-1	
p-2	
p-3	
p-4	
	___
Total (Aver.)	P =

Step 2: Average illumination on plane 30" above floor = _____ Ft-c (I.E.S. Standard Method).

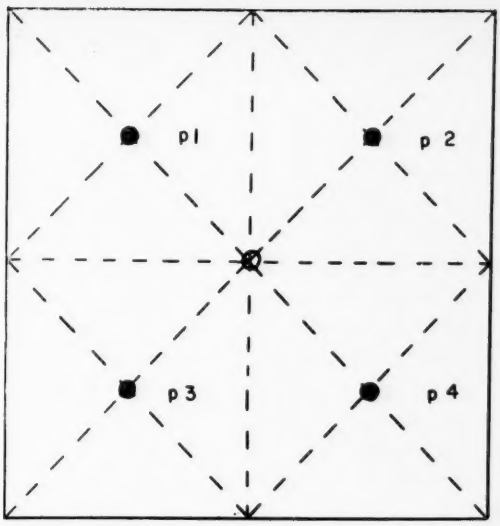


Figure 3.
Measurement procedure in a regular area with a symmetrically located single luminaire.

TABLE V (c).
REGULAR AREA WITH TWO OR MORE CONTINUOUS ROWS OF LUMINAIRES

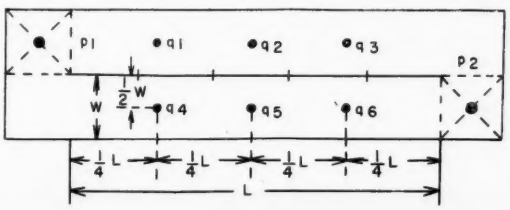
Step 1		Step 2		Step 3		Step 4	
Station	Ft-c	Station	Ft-c	Station	Ft-c	Station	Ft-c
r-1		q-1		t-1		p-1	
r-2		q-2		t-2		p-2	
r-3				t-3			
r-4				t-4			
	___		___		___		___
Total (Aver.)	R =		Q =		T =		P =

Step 5: Average illumination on plane 30" above floor = _____ Ft-c (I.E.S. Standard Method).

TABLE V (d).
REGULAR AREA WITH SINGLE ROW OF CONTINUOUS LUMINAIRES

Step 1		Step 2	
Station	Ft-c	Station	Ft-c
q-1		p-1	
q-2		p-2	
q-3			
q-4			
q-5			
q-6			
	___		___
Total (Aver.)	Q =		P =

Step 3: Average illumination on plane 30" above floor = _____ Ft-c (I.E.S. Standard Method).



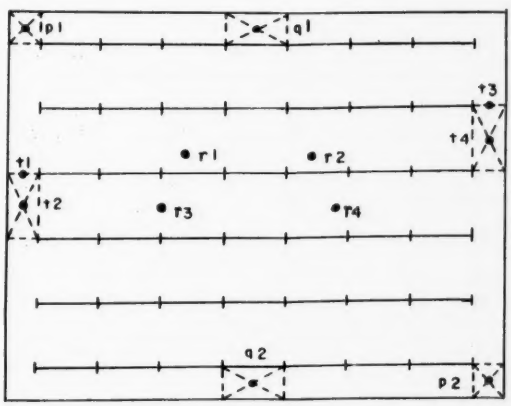


Figure 4.
Measurement procedure in a regular area with two or more continuous rows of luminaires.

Figure 5.
Measurement procedure in a regular area with a single row of continuous luminaires.

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TABLE VI.
SPOT FOOT-CANDLES AT POINT OF WORK AND IN PLANE OF WORK

Work Point	Description of Work Point	Height Above Floor in Feet	Plane (Horizontal, Vertical, or Inclined)	Foot-candles	
				Total (General Plus Supplementary)	General Only
1 - (mk.)					
2 - (min.)					
3 -					
4 -					
5 -					
6 -					

TABLE VII.
FOOT-LAMBERTS (BRIGHTNESS) FROM SPECIFIED WORKPOINT LOCATIONS

Location	A	B	C	D	E	F
			Foot-lamberts			
Luminaire at 45° above eye level						
Luminaire at 30° above eye level						
Luminaire at 15° above eye level						
Ceiling, above luminaire						
Ceiling, between luminaires						
Upper wall or ceiling adjacent to a luminaire						
Upper wall between two luminaires						
Wall at eye level						
Dado						
Floor						
Window shades						
Windows						
Task						
Immediate surroundings of task						
Peripheral surroundings of task						
Highest brightness in field of view						

Description of highest brightnesses, A through F _____

Were brightness readings taken during daytime or nighttime? _____

DAYLIGHTING

What daylighting means are provided? _____

What daylight control means are provided? _____

MAINTENANCE

What is regular cleaning schedule for luminaires? _____

When were luminaires last cleaned? _____

What is lamp replacement schedule: On burn-out _____ Group replacement _____

If group replacement, when was last replacement made? _____

What is group replacement interval? _____ Percentage of lamp burn-outs found _____

What is regular painting schedule? _____ When was area last painted? _____

Is working atmosphere clean, average or dirty? _____

GENERAL OBSERVATIONS ON THE VISUAL ENVIRONMENT

What percentage of workers are subjected to undue direct glare conditions from:

General lighting system _____ Supplementary lighting _____ Daylighting _____

What percentage of workers are subjected to undue reflected glare conditions from:

General lighting system _____ Supplementary lighting _____ Daylighting _____

If there are adjustable daylight control means, are they being used as effectively as possible to minimize glare? _____

What percentage of workers are subjected to troublesome shadows at workpoint? _____

What is your opinion of the general lighting system? (good fair, poor) _____

What is your opinion of the supplementary light? (good, fair, poor) _____

Rate the room as a whole from the standpoint of pleasantness and visual comfort of workers (good, fair, poor) _____

What changes, in your opinion, would effect the most obvious improvement of the visual environment? _____

Other comments: _____

Industrial Medical Association

President's Page

As a result of our intensive membership drive, we have received many letters which have been revealing, interesting and informative. They vary greatly in content and opinion. Some of the writers believe that we should admit to IMA any and all physicians who are interested in any phase of industrial medicine, whereas others are equally positive that membership should be restricted to the full-time men in industry. A few members believe that we should raise dues instead of increasing membership; others advise that our dues be lowered and that we admit all who may wish to become members.

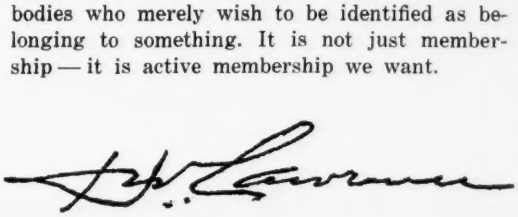
I shall here attempt to present a comprehensive answer to the many and varied opinions submitted.

Quite frankly, we want you in IMA regardless of whether you are full-time, part-time, on call, or in any other industrial situation. We do not want the Industrial Medical Association to be an exclusive society of full-time industrial physicians, because this defeats the basic purpose of our objectives. There are organizations for the specialists in their fields, and IMA does not intend to compete with them or to duplicate their efforts. Most of us belong to several organizations, all of which serve a specific need or purpose. The IMA is the association of general practice to industrial medicine. We are just as interested in the man who devotes five percent of his time to industry as we are in the full-time man or the professor whose interest may be entirely academic.

In order adequately to perform our primary obligations in industry, we must concern ourselves with a great many things other than routine medical practice. The growing complexity of industrial relations and the present day socio-economic climate in which we pursue our profession makes additional knowledge necessary. The individual physician in private practice or in industry, however, has neither the time nor the facilities adequately to keep up with the perpetual parade. IMA is, therefore, quite happy to leave matters of basic research and academic theory to other groups, and prefers to deal more directly with the practical, every-day problems and to reach workable solutions based on the professional experience of its members. IMA is designed to provide you with the meeting ground and clearing house where you can learn of current developments in all phases of industrial medicine.

It is every member's responsibility to see that our association is oriented toward the attainment of these useful and desirable objectives. That is why this deluge of letters from our members is so gratifying. Your interest in IMA affairs is a challenge to your officers to translate obligations into practice. It is our combined responsibility always to advance the best practice and eliminate the worst.

Do not expect the mere fact of IMA membership to enhance your value to industry. Unless you put yourself in position to profit by the informed discussions in your component society meetings or at the Annual Industrial Health Conference, unless you contribute in part and avail yourself of services, the mere fact of belonging to IMA is meaningless. Unless our journal, our news-letters, personal communications, group discussions, and question and answer periods can help you apply this information to your own company situation, then I would say that IMA membership is a poor investment; at least you are not getting the dividends. As an association, we are desirous of attracting to membership active, creative and professionally qualified men. A small number of this type is preferable to a large membership of lukewarm bodies who merely wish to be identified as belonging to something. It is not just membership — it is active membership we want.



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Science Miniature

Corrosive Lesion of the Eye Caused By Liquid SO_2

P. J. SANCHEZ, M.D.
Celanese Mexicana, S.A.
Zacapu, Mich., Mexico

J.M.C., 27 years of age, male, married, profession: chemical engineer, employed by: Celanese Mexicana, in Zacapu, Michoacan, Mexico.

On October 8, 1957, at 2:45 P.M., while opening a five pound cylinder of SO_2, the exhaust hose slipped off of its socket, with the result that liquid SO_2 splashed into left eye of an employee who was manipulating the cylinder. This employee immediately washed and flushed his eye with running water, for approximately 10 minutes, after which he was taken to the medical department. Here the eye was thoroughly flushed with water for another 10 minutes.

The immediate symptoms were complete loss of vision of left eye; the employee gave a description of looking into a dome, as though he were seeing the concavity of his own cornea; he claimed perception of light, but in a faulty manner. He described an intense burning sensation that diminished after the first eye wash. After this the patient stated that he felt as though there was sand in the injured eye.

The clinical signs were as follows: the cornea had lost all transparency and was completely opaque, as if covered by a dense white veil, probably due to coagulation of corneal proteins and to destruction of corneal epithelium (traumatic chemical keratitis). This destruction went as deep as, and apparently included, the membrane of Bowman. There was intense hyperemia and edema of the conjunctiva, which appeared soft and jelly-like (traumatic chemical conjunctivitis); profuse lacrimal secretion; and blepharospasm. The iris was not visible. The result of a test for visual acuity was 0/10.

Upon completing the examination, a 2.5% solution of hydrocortisone acetate was instilled in the injured eye every 15 minutes, and one gram of ascorbic acid was administered intravenously. The eye was covered.

After the first hour, upon the fourth instillation of hydrocortisone acetate, the opacity of the cornea was noticeably regressing. No change was observed in the conjunctiva. The symptoms of slight burning sensation and of foreign body persisted. The patient claimed he could now see; however, his vision was blurred and deficient. The result of a test for visual acuity was still 0/10.

After the third hour, the opacity was noted to be still receding; the cornea appeared slightly transparent to the point of permitting scant visualization of the iris. The patient was released and sent home after an application of Terramycin ophthalmic ointment, and with his eye covered. It was recommended that hydrocortisone acetate be applied every hour instead of every 15 minutes, and Terramycin ointment every 12 hours.

The patient was again examined at his home at 10:00 P.M., but no apparent improvement was noted. The patient stated that around 8:00 P.M. he began to feel pain within the nasal half of the eye ball. Oral Prednisolone was prescribed, 5 mlgr. every six hours; 15 micrograms of vitamin B_{12} were administered intramuscularly.

The following morning at 8:00 A.M., the patient was again examined, with no appreciable change or improvement in symptomatology or in the state of the cornea. The conjunctiva was definitely more edematous. Since the patient complained that the Terramycin ointment produced an intense burning sensation when applied, this was changed to Metimyd, twice daily.

Medication continued thus: Ascorbic Acid, 1 gram daily, intravenously; B_{12}, 15 micrograms intramuscularly, daily; Metimyd ophthalmic ointment, twice a day; 2.5% solution of hydrocortisone acetate every hour; Prednisolone, 5 mlgr. every six hours, orally; eye covered.

No appreciable change took place on October ninth, nor on the morning of October tenth. The cornea was still opaque, vision was still faulty and blurred; the conjunctiva appeared more congested and more edematous. On the afternoon of the tenth, on uncovering the eye, the patient claimed to see much better; examination revealed that exactly in the center of the cornea the opacity had noticeably diminished, apparently due to denudation of the corneal epithelium, and slowly but progressively, from the center to the periphery of the cornea, the process of denudation continued, and in 48 hours this process was totally completed. Pain subsided accordingly.

The denudation of the opaque epithelium permitted clear visualization of the iris; this membrane and the anterior chamber of the eye were normal. A drop of atropine was instilled in order to examine the rest of the eye and the retina; findings were negative.

In spite of the elimination of the corneal epithelium, vision, although greatly improved, was still blurred; the cornea was still not perfectly transparent due to multiple small granulations that appeared on the layer of Bowman. Fluorescein was placed on this membrane, which revealed several small linear scratch-like lesions.

Treatment was continued as before specified, with the following modifications: hydrocortisone acetate every three hours, instead of every hour; vitamin B_{12} was suspended after the fifth injection; Prednisolone was discontinued after the sixteenth tablet. Vitamin E, 125 mlgr. three times daily, orally, was added.

Daily observation thereafter revealed a better appearance of the cornea, since the granulations progressively diminished in size and in number; the scratch-like images did likewise. Not until the ninth day after injury did the conjunctiva begin to show any improvement. From this day on, very slowly, the edema and the hyperemia diminished.

Burning and foreign body sensation diminished accordingly. At this time the eye was left uncovered. On the twelfth day the eye again was tested and 3/10 vision was recorded.

On the seventh of November the eye had a completely normal macroscopic appearance. However, examination under the slit-lamp revealed a few persisting granulations. Vision on this day was 5/10. Evident and total disappearance of the lesions of the patient's eyes, observed under the slit-lamp did not take place until December second. Vision on this day was 8/10.

Treatment was continued through the fifteenth day after injury. From this day until the second of December medication was limited to Vitamin E, 125 mlgr. three times daily, and local treatment was restricted to a combination of fluohydrocortisone acetate, Neomycin and Gramicidin, twice daily.

On December second, all medication was discontinued. The patient was asymptomatic and no abnormal signs were detected in the eye. Vision, as before stated, was 8/10; this slight defect in visual acuity is due to concomitant astigmatism, and was corrected with eye-glasses. The astigmatism was considered permanent.

The routine pre-employment examination of this person, performed on November 22, 1955, revealed visual acuity of left eye, 9/10. The patient did not wear eye-glasses at this time. How much of this very scant difference of loss of vision can be attributed to the described injury is not known. The two years that elapsed between his pre-employment examination, and this injury, could have accounted for the slight difference in vision. During this lapse of time the employee did not wear eyeglasses.

Letters

Tetanus Immunization Register

Under your issue of September, 1958, entitled "Science Miniature" there is a request by Dr. N. Gilmore Long for registers for tetanus immunizations. It might be of interest to know that the same thoughts have been held by those of us in the Medical Department here in the Springfield Works of the Allis Chalmers Manufacturing Company. It was approximately four years ago, through the help of our chief nurse, Mrs. Alta Whitely, that we devised a record which is carried by the men and entails all the necessary information to help them in company accidents and in non-industrial situations. Specifically, we make note of any allergies or horse serum reaction and any other immunizations which they may need or be given. The card is of firm paper stock and is grooved in the center so that it may be folded face in and the patient may carry it with him in his wallet.

These have become very popular with the men at Allis Chalmers and also with my personal practice serving a successful reminder to these people for further immunizations.

—JOHN G. MEYER, JR., M.D.

Books

Parsimonious — Or Disastrous

TRANSPORTATION OF THE INJURED: CARL B. YOUNG, JR., M.P.H. Charles C. Thomas, Springfield, Illinois, 1958, pp. 238, $6.75.

The adage that "Nothing is more complex than the absence of complexity," perhaps should be altered to "Nothing is more complex than the absence of simplicity." The transportation of injury victim from the site of injury to the hospital or elsewhere could be the simplest step in the train of affairs from accident to full recovery, provided all the proper things are done and done at the proper time. Transportation of the injured may be fraught with jeopardy; hence this book.

Its contents fall naturally into two divisions: Section one of this manual has been prepared for the use of ambulance crews, law enforcement and fire service personnel, industrial nurses and others directly responsible for the handling of the injured.

Section two has been written for the administrative heads of city governments, city and county police and fire departments, health units, hospitals, undertakers, ambulance service companies, county medical societies and community leaders — in short, for all who legally and morally are responsible for providing the people of any community with efficient ambulance service.

When an injury occurs, "safety" already has failed, but this book stands close to safety in the warding off of further injury after injury. Not since the invention of the "safety pin" have many developments promised more obvious gains than those prospective from the application of the principles this book offers.

Touch Your Toes

THERAPEUTIC EXERCISE: SIDNEY LICHT, M.D., Editor. Elizabeth Licht, New Haven, Conn., 1958, pp. 893, $16.00.

Here is no series of cheerful exhortations to go about a brisk six-block walk every night as conducive to sound sleep or to the bouncing around on some mechanical horse in a gymnasium as an aid to digestion. Instead, this is an elaborate presentation of the fundamentals of exercise and their application to many forms of disease involving muscular impairment. At the outset there appears extensive information on the Motor Unit, the Physiology of Exercise, the Mechanics of Motion and Posture. This is followed by consideration of motions of various portions of the body and procedures of examination of such areas. The major portion of the contents is devoted to exercises in specific conditions including scoliosis, poliomyelitis, amputations, arthritis, hemiplegia, cerebral palsy, multiple sclerosis. In time, numerous chapters are directed to pathological states in which muscle impairment is not characteristic, such as in mental disease, pulmonary disease, vascular disease and obstetrics. Finally, a single chapter of four pages is directed to exercise for healthy persons.

All considered, it is astonishing to discover that

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such a volume has grown up around therapeutic exercise. The emphasis at all times is upon exercise as a therapeutic instrument and not upon exercise as a part of everyday life.

The Enemy — The Cold

COLD INJURY, GROUND TYPE: Prepared under direction of MAJOR GENERAL S. B. HAYS, The Surgeon General, United States Army. U. S. Government Printing Office, 1958, illustrated, pp. 570, $6.25.

There is little doubt that this is the most comprehensive volume on the ground type of cold injury which has been published. It contains a complete historical account of the condition in all recorded wars, as well as complete chapters on the World War II experience of the United States Army in Alaska, Europe and the Pacific, where the so-called tropical type was briefly encountered. There are chapters on every other phase of cold injury, from pathogenesis to prevention and control; the chapters on epidemiology and on the clinical aspects of the condition being particularly detailed. The book is thoroughly illustrated, with some illustrations in color.

The enormous public interest aroused in the incidence of cold injury during World War II was well founded; the United States Army suffered more than 90,000 casualties from it. The late General George S. Patton was stating no more than the facts when he said that during the height of the epidemic in the winter of 1944, we had about conquered the Germans, but cold injury seemed well on its way to conquering us.

Lo, The Low Back

LUMBAR DISC LESIONS, PATHOGENESIS AND TREATMENT OF LOW BACK PAIN AND SCIATICA: J. R. ARMSTRONG. Williams and Wilkins, Baltimore, pp. 244, second edition, 1958, $12.00.

Low back disorders are so common that it is interesting to speculate why this region should be such a weak spot in the human locomotor system. When, long ago in late Oligocene times, man forsook the trees to walk upright on the ground, he made novel demands on his lumbosacral spine. It may be that the adaptive process is incomplete.

Only in the past 20 years has any satisfactory classification of these disorders become possible. Before this, the gaps in our knowledge were too great to permit a clear picture to be formed. With the recognition of disc lesions many previously inexplicable clinical phenomena were understood, and interest in these lesions stimulated much research and a new approach to the problems of the low back.

There is hardly any group of ailments which requires such careful evaluation when planning treatment as lesions of the lower lumbar intervertebral discs. A great deal of both good and bad material has been written about them in the last 20 years, and there will no doubt be more in the future. The present monograph is the product of accurate and inquisitive clinical observation, a comprehensive survey of the literature and an experience of more than 1,000 well documented operations. Mr. Armstrong is deliberately provocative, didactic and repetitive; there is much in the story of the prolapsed intervertebral disc which deserves and, indeed, requires repetition. His work portrays for the most part the views of contemporary British orthopedic surgeons. For example, it is rightly pointed out that a degenerative disc lesion produces a mechanical disturbance of the spine which may have far-reaching consequences. Involvement of a root of the sciatic nerve is often the most dramatic presentation in the clinical picture, but the cure of the sciatica either by conservative or operative means is not always the end of the story, as some surgeons appear to think.

The Balance of Nature

USES OF EPIDEMIOLOGY: J. N. MORRIS. Williams and Wilkins Company, Baltimore, 1957, pp. 135, $4.00.

Occupational health suffers from not having discovered epidemiology. This author pleadingly holds out epidemiology as a contributor to the solution of all manner of preventive medical difficulties with some scant mention of dangerous trades. For American usage there is a little too much of the British flavor, but the working applications are suitable whether needed in Greenock or Kokomo. Foremostly, this is an idea book. It is not a text and disclaims comprehensiveness. Yet, it teems with provocation. At one point, in presenting population trends, the author forecasts future sex ratios. He notes:

What seems to be keeping the male death rate in middle-age even as moderately satisfactory as it is now, is the balancing of those diseases which are increasing (such as "coronary thrombosis") by those which are declining (tuberculosis and other infections). If the decline of the infectious diseases is halted before the modern epidemics are brought under control, and if the conditions which are relatively stationary (cancer of the stomach, cerebrovascular disease, for example) do not show improvements in the meanwhile, the overall middle-aged male death rate will actually begin to rise. This may already be happening in Scotland where the position is in several respects less favorable. The average death rates in that country since the first world war have been such that in the years 1951-54 for every 1,000 of population in the years 55 to 64, deaths for males have been 25.7 versus 14.5 for females. One consequence of these trends if they persist would be that the population of old people in the future will consist more and more of solitary old women, whatever the increasing popularity of marriage during recent years. Already, about a third of men reaching 35 years of age die before 65 compared with about 20% of women. This current trend of mortality in middle-aged men is the most disquieting feature of Western vital statistics. There is no ready answer in terms of living standards, animal fat consumption, industrialisation, urban living, economic advance, tempo of social change.

The agile minded industrial physician should see in those preceding statements at least two prospects. One is the probability of higher percentages of women industrial workers in any time of labor shortage; the other is that this situation may attract more women physicians into the occupational health work. The future does not look any too bright for the misogynists.

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Vision and Lighting in Public Speaking

Just to prove that the millennium in vision and lighting actually is not at hand, some of the speakers of the conference of which this issue is the published record, themselves made victims of the audience by presenting lantern slides with the very same visual defections that were condemned in much of the coverage of this conference. All too many slides were crowded; some backgrounds were unsuitable; many slides were too bright; and the auditorium itself was not made contributory to the events through the elimination of all general lighting. In an effort to make its own contribution to the coverage of this conference, albeit chiefly through the process of borrowing, this Journal introduces extracts from an editorial by Richard A. Kern, M.D., entitled "How to Present a Scientific Paper Before a Large Audience," presented in the *Annals of Internal Medicine*:

"Visual aid by lantern slides is useful to illustrate something by picture, to convey a concept by diagram and to emphasize salient facts or data, provided your slide technique is good. But a poor slide technique can ruin your presentation even more surely than can any of the mistakes thus far mentioned. Here are the chief points to be kept in mind to get the best results:

"The number of slides to be shown is a function of the time limit assigned. It usually takes over one minute per slide; very few take less and some considerably more. Repeated time trials for the slides are more important to make than those for text, since slides are more likely to go overtime and are harder to speed up.

"The size of slides should correspond whenever possible to that of the standard projector available: 3¼ x 4 inches. If for any reason some other size must be used, be sure not only to get confirmation in writing well in advance of the availability of the size and type of projector you require, but to verify its presence before the meeting starts.

"Have your material centered and well within the projectable portion of the slide. This will save you the embarrassment of having a picture decapitated, or the total at the foot of a column chopped off, or the beginnings or ends of lines of text deleted, and also the unanticipated loss of time in asking the operator to shift the slide or raise or lower the lantern.

"Top and bottom are cut off more frequently, especially if you arrange your material in a rectangle whose long dimension is perpendicular. Such slides work perfectly in all classrooms where the screen is square. But in nearly every large auditorium the screen is rectangular with the long dimension horizontal, because the screen is intended primarily for the projection of motion picture film whose frames are rectangles that are invariably horizontal.

"But the lateral edges are also vulnerable, because in a large auditorium the projection lantern is placed as far back as possible in order to get the maximum of magnification which the full width of the screen will allow. Therefore, use a mat to be sure your material is properly centered and limited: the opening of the mat should not exceed 2½ x 3 inches.

"If the slide presents a picture or a photomicrograph, make use of such devices as an arrow or circle to call prompt attention to the important

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features. As you talk about the slide, you can then mention the ringed area without using the pointer that someone forgot to provide. Be sure to write out every word of your comment on the slide so that it, too, will be properly timed.

"The use of the electric torch arrow pointer calls for comment. Get to the meeting place early to familiarize yourself with this useful gadget. In using it, point it at once to the item you mean to stress and turn it off promptly when that purpose has been served, or else point it directly at your feet until you need it again. It is most disconcerting for the audience to follow the arrow's aimless wanderings all over the screen in anticipation of another point of emphasis that never comes. Between applications, don't shine it in the faces of those in the front row or that of the chairman.

"If the slide presents a diagram or figure, this should be so simple that it can be grasped within seconds and understood without reference to a blueprint. The use of contrasting colors makes the figure more intelligible and easier to explain.

"If the slide presents data they should be minimal. Those most significant should be so designated by means of contrasting colors, or boldfaced type, or underlining or combinations of these devices.

"If the slide presents facts in text form, they should be few, arranged preferably in outline form and with the separate members of the outline identified by numbers.

"In planning the arrangement of all slide material, take a leaf out of the book of the commercial advertiser. He knows he has only seconds to catch the eye of the public so he uses the simplest picture, the fewest words, the brightest colors, the biggest type for the most important thought, all to make the most striking effect at a glance.

"Visibility by the man in the last row is the chief factor that limits the amount of material that should go on a slide. In order to be legible the width of every part of a letter must subtend an angle of 1′, and the height and width of the whole letter must subtend an angle of 5′; that is, an angle whose apex is at the pupil of the viewer and which has an opening of 5′, the overall dimension of the letter. This fact is the basis of the Snellen Test Chart for measuring visual acuity. To subtend an angle of 5′ at the pupil of the man in the last row 200 feet from the screen, the letter on the screen must be three inches high and wide. (Multiply the distance from the screen by 0.001425 to get the dimension of the letter.) If the screen is 15 feet wide, then a single line of text on the screen can have no more than 60 letters and spaces if that text is to be readable by a man with 20/20 vision in the last row. To be easily readable, the line must have decidedly fewer letters and spaces.

"Leave the slide on the screen long enough for everyone to read it. This usually takes half-again as long for the other fellow as it does for you, so give him a break in your timing.

"It is better to signal for the next slide with a buzzer or 'clicker,' if available, than to say 'next slide,' lest the operator mistake a word in your text for such a signal. A recent speaker lost valuable time because the operator shifted slides when he heard the word, 'Dextran.'

"These have been the 'Do's' to be observed in lantern slide technic. Even more important are the 'Don't's.'

"The most important one is this: Don't put too much on a slide. If it is a picture or a photomicrograph, don't have too much irrelevant material, such as the whole cross-section of an organ, thereby dwarfing into insignificance the crucial part of the picture. If you wish to show proportion or relations, then use a second slide for further detail.

"Don't project a complicated diagram, it takes too long to decipher.

"Don't put too many data on a single slide, especially irrelevant data. Yet this unhappy mistake is the one most frequently committed. The author is too lazy to construct a brief summary of salient data, so he photographs instead a detailed table that will occupy a full page in the printed paper.

"Don't project whole paragraphs of running text. Use outline form and telegraphic style to get the few important facts across most quickly. If there are more facts, use two slides.

"Don't distract your audience in any of the following ways: Don't talk away from the slide on the screen, your comments should be to emphasize or amplify what is in sight, not to present new ideas. Don't leave a slide on the screen when it is no longer needed. If you have something new to say before going on to the next slide, ask for 'lights, please,' or signal the operator by means of a blank slide or by a white card properly placed in your series of slides.

"Don't frustrate your audience by whisking a slide off the screen before they have had time to read it.

"Don't waste the time of your audience by reading every word and figure on the screen. They can read, too, so confine yourself to brief relevant comments.

"Don't use slides with white letters on a black background; their visibility is much less than that of slides with black letters on a white background." RICHARD A. KERN, M.D.

From *Annals of Internal Medicine*, 42:618, 1952. RICHARD A. KERN, M.D.

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